

LEVE



VOLUME 13, NO. 12,
DECEMBER 1981

A108290

AD A109583

THE SHOCK AND VIBRATION DIGEST

A PUBLICATION OF
THE SHOCK AND VIBRATION
INFORMATION CENTER
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

DTIC
SELECTED
JAN 13 1982
A

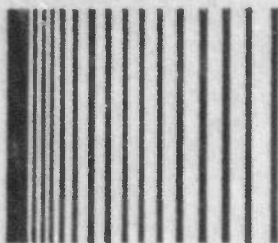
DTIC FILE COPY



OFFICE OF
THE UNDER
SECRETARY
OF DEFENSE
FOR RESEARCH
AND
ENGINEERING

82 01 13 078

389004



THE SHOCK AND VIBRATION DIGEST

Volume 13, No. 12
December 1981

STAFF

SHOCK AND VIBRATION INFORMATION CENTER

EDITORIAL ADVISOR: Henry C. Pusey

VIBRATION INSTITUTE

TECHNICAL EDITOR: Ronald L. Eshleman

EDITOR: Judith Nagle-Eshleman

RESEARCH EDITOR: Milda Z. Tamulionis

PRODUCTION: Deborah K. Howard
Gwen Wassilak
Vicki Pate

BOARD OF EDITORS

R. Belshaim	W.D. Pilkey
R.L. Bort	E. Sevin
J.D.C. Crisp	J.G. Showalter
D.J. Johns	R.A. Skop
K.E. McKee	R.H. Volin
C.T. Morrow	H.E. von Gierke



A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

Code 5804, Naval Research Laboratory
Washington, D.C. 20375 \$100.00

Henry C. Pusey
Director

Rudolph H. Volin

J. Gordon Showalter

Jessica P. Hileman

Elizabeth A. McLaughlin

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman
Vibration Institute
Suite 206
101 West 55th Street
Clarendon Hills, Illinois 60514

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of \$140.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendar year, beginning with the January issue. Back issues are available - Volumes 9 through 12 for \$15.00. Orders may be forwarded at any time to SVIC, Code 5804, Naval Research Laboratory, Washington, D.C. 20375. Issuance of this periodical is approved in accordance with the Department of the Navy Publications and Printing Regulations, NAVEXOS P-35.

SVIC NOTES

WHERE DID THAT NUMBER COME FROM?

Dynamic test requirements for equipment in vehicles often include numerical values and many users ask the question, "where did that number come from?" Interest in this subject is continuous but current efforts to revise MIL-STD-810, and requirements for test tailorability and for the disclosure of the rationale behind the numbers in test documents, have increased the awareness of this subject. Many methods have been used to set dynamic test requirements for vehicle equipment; it might be useful to briefly mention some of the more common of these.

First, if equipment is to be installed in an existing vehicle the establishment of test requirements might be simplified provided inputs from the vehicle to the item are available or can be measured.

If equipment is being developed for new vehicles it is only possible to establish preliminary test requirements at first because the equipment is usually developed before the vehicle exists. A typical orderly procedure includes the prediction of the expected dynamic environment followed by verification during field or laboratory tests once the prototype vehicle has become available. Many believe that preliminary test requirements should be slightly conservative to avoid the need to redesign the equipment and possible contractual difficulties if the operating environments turn out to be more severe than expected. Further details of this process have appeared in many of the previous *Shock and Vibration Bulletins* and papers on establishing qualification test requirements for airborne equipment will be published in the proceedings of the 53rd Meeting of the Advisory Group for Aerospace Research & Development (AGARD) Structures and Materials Panel which was recently held in the Netherlands.

Another method for setting dynamic test requirements for equipment in new vehicles is to use standards documents that contain guidelines that may be used to either derive test requirements or to establish the actual values of the dynamic test levels. Many prefer to use standards because they are convenient and often no other guidance is available. However, care must be taken in their use to avoid misinterpretation and this can only be done if the rationale behind the standard is known and understood. Many examples of the use of standards for establishing suitable dynamic test requirements for equipment in new vehicles are also available in the literature.

The foregoing are some of the more common methods for setting dynamic test requirements and other methods are available; some involve a combination of two or more of the methods that were previously mentioned, some are based on known physical limitations and still others are arbitrary. The most important requirements for any method for setting dynamic test requirements are that they must be as realistic as possible and that the rationale behind their numbers should be thoroughly documented.

R.H.V.

EDITORS RATTLE SPACE

DISTILLATION OF THE LITERATURE

Each year the twelfth issue of the *DIGEST* gives an indication of the volume of literature published in the shock and vibration area: there were almost 2700 abstracts published in the *DIGEST* in 1981. This represents a 40 percent increase in publications since 1978. At this rate of growth one wonders when the publishing system will go unstable and self destruct!

The increasing number of abstracts means that more and more information is being written in the shock and vibration field. More technology is thus available to the engineer trying to solve problems. Unfortunately, more is not always better. The large volume of literature means that the engineer will have to use valuable time attempting to identify pertinent articles and information. It is true that the abstract of an article or report can be retrieved as part of a subject or problem area, but this is only the beginning of the process of identifying what literature may be helpful in solving a problem or advancing a research and development project. The articles must be studied and analyzed to determine the available pertinent information. As the volume of literature increases, so does the time required to distill it. This brings us to the point of this editorial: the effort expended on literature reviews and distillation should increase in proportion to the growing volume of literature.

In past years the literature was distilled in textbooks and specialized technical books. This was and is a slow process. Today the distillation of the literature in book form is not keeping up with the growing volume of literature. The literature review section of the *DIGEST* is devoted to distillation of the literature – and is meant to provide an objective analysis of the literature. Many literature review articles are published in the *DIGEST* and in other journals, but other specific technical areas should also be reviewed. I feel that more effort should go into the writing of review articles. If you are interested in writing a review article, please contact the editors of the *DIGEST*.

R.L.E.

SEARCHED	<input checked="" type="checkbox"/>
SERIALIZED	<input type="checkbox"/>
INDEXED	<input type="checkbox"/>
FILED	<input type="checkbox"/>
100-80	
A 21	

FINITE-ELEMENT MODELING OF LAYERED, ANISOTROPIC COMPOSITE PLATES AND SHELLS: A REVIEW OF RECENT RESEARCH

J.N. Reddy*

Abstract. *This paper reviews finite element papers published in the open literature on the static bending and free vibration of layered, anisotropic, and composite plates and shells. The paper also contains a literature review of large-deflection bending and large-amplitude free oscillations of layered composite plates and shells. Non-finite element literature is also cited for continuity of the discussion.*

In recent years composites, especially fiber-reinforced laminates, have found increasing application in many engineering structures. This is mainly due to two desirable features of fiber-reinforced composites: a high stiffness-to-weight ratio and the anisotropic material property that can be tailored through variation of the fiber orientation and stacking sequence of lamina – a feature that gives the designer flexibility. The increased use of fiber-reinforced composites as structural elements has generated considerable interest in the analysis of laminated (anisotropic) composite plates and shells.

Recent developments in the analysis of plates and shells laminated of fiber-reinforced materials indicate that thickness has a more pronounced effect on the behavior of composite laminates than on isotropic laminates. Classical thin-plate and thin-shell theories assume that normals to the midsurface before deformation remain straight and normal to the midsurface after deformation; the implication is that thickness shear deformation effects are negligible. As a result, natural frequencies calculated using the thin-plate theory are higher than those obtained by including transverse shear deformation effects. In addition, the transverse deflections predicted by thin-plate theory are lower than those predicted by shear deformable theory (SDT). Due to the low transverse shear modulus relative to the in-plane Young's moduli, transverse shear deformation effects are even

more pronounced in composite laminates. Reliable prediction of the small deflection response characteristics of high modulus composite plates and shells therefore requires the use of shear deformable theories.

When the transverse deflections experienced by plates and shells are not small compared to laminate thickness, the interaction between membrane stresses and the curvatures – bending and shear – of the laminate must be considered. The interaction results in midplane stretching, which leads to nonlinear terms in the equations of motion. Thus, a more accurate prediction of deflections, stresses, and frequencies requires a solution of the laminate equations that can account for large deflections and thickness shear deformation.

LITERATURE REVIEW OF PLATES

Small-deflection theory of plates. A number of shear deformable theories for laminated plates have been proposed to date. The first theory for laminated isotropic plates is that of Stavsky [1]. The theory has been generalized to laminated anisotropic plates by Yang, Norris, and Stavsky [2]. Their work, called the Yang-Norris-Stavsky (YNS) theory, represents a generalization of Reissner-Mindlin plate theory for homogeneous isotropic plates to arbitrarily laminated anisotropic plates and includes shear deformation and rotatory inertia effects. A review of other theories, for example, the effective stiffness theory of Sun and Whitney [3], the higher-order theory of Whitney and Sun [4], and the three-dimensional elasticity theory of Srinivas et al [5-7], has been reviewed in [8]. It has been shown [3, 5, 9-13] that the YNS theory is adequate for predicting such overall behavior as transverse deflections and natural frequencies (first few modes) of laminated anisotropic plates.

*Professor, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

The first application of the YNS theory is apparently due to Whitney and Pagano [14], who presented closed-form solutions for symmetric and antisymmetric cross-ply and angle-ply rectangular plates under sinusoidal load distribution and for free vibration of antisymmetric angle-ply rectangular plates. Fortier and Rosettos [15] analyzed the free vibration of thick rectangular plates of unsymmetric cross-ply construction; Sinha and Rath [16] considered both vibration and buckling for the same type of plates. Following Whitney and Pagano [14], Bert and Chen [17] presented a closed-form solution for the free vibration of simply supported rectangular plates of antisymmetric angle-ply laminates.

Finite-element analysis of layered composite plates began with Pryor and Barker [18] and Barker, Lin, and Dana [19], who employed an element with seven degrees of freedom (three displacements, two rotations, and two shear slopes) per node to analyze thick laminated plates. Mau, Tong, and Pian [20] and Mau, Pian, and Tong [21] used the so-called hybrid-stress finite-element method to analyze thick composite plates. Noor and Mathers [22, 24] used finite element models based on a form of Reissner's plate theory -- i.e., mixed formulation -- to study the effects of shear deformation and anisotropy on the response of laminated anisotropic plates. One of the elements used had 80 degrees of freedom per element and thus required enormous computational resources. Hinton [24] used the so-called finite strip method to study the free vibration of layered cross-ply laminated plates. Mawanya and Davies [26] and Panda and Natarajan [27] used the quadratic shell element of Ahmad, Irons, and Zienkiewicz [28] to analyze the bending of thick multi-layer plates. Spilker, Chou, and Orringer [29] used two hybrid-stress elements to study the static bending of layered composite plates. The number of degrees of freedom in one of the two elements is proportional to the number of layers; therefore, the core storage and execution time requirements for the element increase rapidly with the number of layers in the plate. Reddy [30] recently developed a simple and efficient finite element based on the YNS theory. The element contains three displacements and two bending slopes as degrees of freedom per node. The accuracy and convergence characteristics of the element have been investigated [31]. The element has been used successfully in the free vibration and

thermoelastic analysis of ordinary and bimodulus (i.e., different elastic properties in tension and compression) layered composite plates [30-34].

Large-deflection theory of plates. Much of the research in the analysis of composite plates is limited to linear problems. This is perhaps due to the complexity of the nonlinear partial differential equation associated with the large-deflection theory of composite plates. Approximate solutions to the large-deflection theory (in the von Karman sense) of laminated composite plates have been attempted [35-43]. Chandra and Raju [38, 39] and Chia and Prabhakara [41, 42] employed the Galerkin method to reduce the governing nonlinear partial differential equations to an ordinary differential equation in time for the mode shape; the perturbation technique was used to solve the resulting equation. Zaghloul and Kennedy [40] used a finite-difference successive iterative technique in their analysis. In all of these studies with one exception [43], the transverse shear effects were neglected. The finite element employed by Noor and Hartley [43] includes the effect of transverse shear strains; however, it is algebraically complex and involves a large number of degrees of freedom per element. The use of such elements can thus be precluded in the nonlinear analysis of composite plates. Reddy and Chao [44, 45] recently adapted a shear deformable finite element [30] to the nonlinear bending of composite plates.

Analysis of nonlinear vibration of single-layer orthotropic plates has been done [46, 47]. Nowinski [48, 49] analyzed rectilinearly orthotropic plates of circular and triangular planforms using the Galerkin method; the effects of transverse shear deformation and rotatory inertia were not considered. Wu and Vinson [50] presented the dynamic analogue of Berger's equation of motion for an orthotropic plate, including the effect of transverse shear deformation and rotatory inertia; however, the solutions were restricted to transverse shear deformation. Mayberry and Bert [51] presented experimental as well as theoretical work on nonlinear vibration of laminated plates; the theoretical investigation was limited to a single-layer specially orthotropic rectangular plate with all four edges clamped and did not include the effect of transverse shear deformation and rotatory inertia. Nowinski [52] and others [53] used an assumed mode shape and Galerkin method to present a general equation for the nonlinear

analysis (i.e., large deflection and large amplitude free vibration) of orthotropic plates. Prabhakara and Chia [54] presented an analytical investigation of the nonlinear vibration of a rectangular orthotropic plate with all simply supported and all clamped edges. The effect of transverse shear and rotatory inertia on large amplitude vibration of composite plates was reported recently by Sathyamoorthy and Chia [55-57]. They used the Galerkin method and the Runge-Kutta numerical procedure.

In general, layered composite plates exhibit coupling between the in-plane displacements and the transverse displacement and shear rotations. For plates having layers stacked symmetrically with respect to the midplane, the bending-stretching coupling terms vanish and the problem is relatively simpler. Wu and Vinson [58] extended their earlier work [50] to deal with the nonlinear vibration of symmetrically stacked laminated composite plates. The first nonlinear vibration analysis of unsymmetrically laminated plates is that of Bennett [36], who considered simply supported (with immovable edges) angle-ply plates. Bert [37] used the thin plate theory of layered composite plates and the Galerkin method to investigate the nonlinear vibration of a rectangular plate arbitrarily laminated of anisotropic material. A multimode (two-term) solution for nonlinear vibration of unsymmetric all-clamped and all-simply supported angle-ply and cross-ply laminated plates was reported by Chandra and Basava Raju [38, 39, 59]. Chandra [39] used a one-term Galerkin approximation for the dynamic von Karman plate equations and the perturbation technique for the resulting ordinary equation in time to investigate the large-amplitude vibration of a cross-ply plate that is simply supported at two opposite edges and clamped at the other two edges. Prabhakara and Chia [54] presented an analytical investigation of the nonlinear free flexural vibrations of unsymmetric cross-ply and angle-ply plates with all-clamped and all-simply supported edges. The normal and tangential boundary forces in the plane of the plate were assumed to be zero. Reddy [60, 61] and Reddy and Chao [62] recently investigated the large-amplitude free vibration of layered composite plates using the finite-element method; they considered transverse shear and rotatory inertia effects. The finite-element studies [60, 62] are apparently the first to consider the nonlinear vibrations of layered anisotropic composite plates including transverse shear deformation.

Additional references, especially those before 1980, can be found in survey articles [63-67].

LITERATURE REVIEW OF SHELLS

Small-deflection theory of shells. The first analysis that incorporated the bending-stretching coupling (due to unsymmetric lamination) in shells is that of Ambartsumyan [68, 69]. He assumed that the individual orthotropic layers were oriented so that the principal axes of material symmetry coincided with the principal coordinates of the shell reference surface. Thus, Ambartsumyan's work dealt with what is now known as laminated orthotropic shells rather than with laminated anisotropic shells. In laminated anisotropic shells the individual layers are generally anisotropic; in addition, the principal axes of material symmetry of the individual layers do not coincide with the principal coordinates of the shell.

In 1962 Dong, Pister, and Taylor [70] formulated a theory of thin shells laminated of anisotropic material. The theory is an extension of that developed by Stavsky [71] for laminated anisotropic plates to Donnell's shallow shell theory [78] of shells. Cheng and Ho [73] analyzed laminated anisotropic cylindrical shells using Flugge's shell theory [74]. Bert [75] combined Vlasov's shell theory [76] with the most general anisotropic constitutive equations of Stavsky [71] to obtain an arbitrary shell geometry. A first-approximation theory for the unsymmetric deformation of nonhomogeneous, anisotropic, elastic cylindrical shells was derived by Widerra and Chung [77]; they used the asymptotic integration of the elasticity equations. For a homogeneous, isotropic material the theory reduces to the Donnell equations [78]. An exposition of various shell theories is available [79].

All of the theories discussed above are based on Kirchhoff-Love's hypotheses [72], in which transverse shear deformation is neglected. The effect of transverse shear deformation and transverse isotropy, as well as thermal expansion through the shell thickness have been considered by Zukas and Vinson [80] and Dong and Tso [81]. The theory used by Dong and Tso [81] is applicable only to layered, orthotropic, cylindrical shells; i.e., the orthotropic axes of each layer coincide with the coordinate axes of the shell. Whitney and Sun [82] developed a shear deformable

theory for laminated cylindrical shells that includes transverse shear deformation and transverse normal strain as well as expansional strains. Widera and Logan [83, 84] recently presented refined theories for nonhomogeneous anisotropic cylindrical shells.

As far as the finite-element analysis of shells is concerned, layered composite shells have not received the attention given to ordinary shells. The works of Dong [85] on statically-loaded orthotropic shell of revolution, Dong and Selna [86] on free vibration of the same, Wilson and Parsons [87] on static axisymmetric loading of arbitrarily thick orthotropic shells of revolution, and Schmit and Monforton [88] on laminated anisotropic cylindrical shells are the only ones that considered the finite-element method before 1970. The last reference is the only one that considered laminated anisotropic shells. During the 1970s there was increased interest in the finite-element analysis of bending and vibration of laminated anisotropic shells. A finite-element application in laminated anisotropic shells of arbitrary geometry is due to Thompson [89], who presented free vibration of general laminated anisotropic thin shells. Other finite-element analyses of layered anisotropic composite shells are available [90-100]; the effect of shear deformation was included in two papers [93, 100].

Large-deflection theory of shells. Despite the importance of nonlinear analyses of layered anisotropic shells, there is apparently no literature on the subject with the exception of the mixed finite-element analysis of Noor and Hartley [101] and recent work by Chang and Sawamiphakdi [102] and Reddy [103]. The work [102] utilizes a degenerated three-dimensional isoparametric element based on an updated Lagrangian description. In [103] a shear flexible finite element was developed based on a shell theory that combines various first-approximation shell theories [72, 78, 104-106]. The theory also accounts for large rotations.

CONCLUDING REMARKS

The bending and vibration analysis of layered anisotropic composite plates and shells is more complicated – due to bending-stretching coupling – than is the classical, isotropic, homogeneous analysis of

plates and shells. Because of these complexities, the available literature is sparse, especially in the area of nonlinear analysis of shells, compared to that of ordinary plates and shells.

Although the first-order shear deformable theories of layered composite plates yield acceptable solutions for global response of plates and shells, the theories do not accurately predict stress singularities and higher-order frequencies. The questions relating to interlaminar stresses, edge effects, and delamination in composites [107-116] can be addressed only when higher-order, three-dimensional theories are employed [82, 117-120].

As the use of composites for high performance design applications increases, the need for more realistic theoretical and experimental prediction of the response characteristics of composite-material structures will become increasingly important.

ACKNOWLEDGMENT

Support of this work by the Structural Mechanics Program of the Air Force Office of Scientific Research (Grant AFOSR-81-0142) and the Structures Research Section of the NASA (Lewis Grant NAG. 3-208) is gratefully acknowledged.

REFERENCES

1. Stavsky, Y., "On the Theory of Symmetrically Heterogeneous Plates Having the Same Thickness Variation of the Elastic Moduli," Topics in Applied Mechanics, (Abir, D., Ollendorff, F., and Reiner, M., Eds.), American Elsevier (1965).
2. Yang, P.C., Norris, C.H., and Stavsky, Y., "Elastic Wave Propagation in Heterogeneous Plates," Intl. J. Solids Struct., 2, pp 665-684 (1966).
3. Sun, C.T. and Whitney, J.M., "Theories for the Dynamic Response of Laminated Plates," AIAA J., 11, pp 178-183 (1973).
4. Whitney, J.M. and Sun, C.T., "A Higher Order Theory for Extensional Motion of Laminated Composites," J. Sound Vib., 30, pp 85-97 (1973).

5. Srinivas, S. and Rao, A.K., "Bending, Vibration and Buckling of Simply Supported Thick Orthotropic Rectangular Plates and Laminates," *Intl. J. Solids Struc.*, 6, pp 1463-1481 (1970).
6. Srinivas, S., Joga Rao, C.V., and Rao, A.K., "An Exact Analysis for Vibration of Simply Supported Homogeneous and Laminated Thick Rectangular Plates," *J. Sound Vib.*, 12, pp 187-199 (1970).
7. Hussainy, S.A. and Srinivas, S., "Flexure of Rectangular Composite Plates," *Fibre Sci. Tech.*, 8, pp 59-76 (1975).
8. Bert, C.W., "Analysis of Plates," *Structural Design and Analysis, Part I* (Chamis, C.C., Ed.), Academic Press, (1974).
9. Pagano, N.J., "Exact Solutions for Composite Laminates in Cylindrical Bending," *J. Composite Matls.*, 3 (3), pp 398-411 (1969).
10. Pagano, N.J., "Exact Solutions for Rectangular Bidirectional Composites and Sandwich Plates," *J. Composite Matls.*, 4, pp 20-34 (1970).
11. Pagano, N.J. and Hatfield, S.J., "Elastic Behavior of Multilayer Bidirectional Composites," *AIAA J.*, 10, pp 931-933 (1972).
12. Whitney, J.M., "The Effect of Transverse Shear Deformation on the Bending of Laminated Plates," *J. Composite Matls.*, 3 (3), pp 534-547 (1969).
13. Mau, S.T., "A Refined Laminated Plate Theory," *J. Appl. Mechanics, Trans. ASME*, 40, pp 606-607 (1973).
14. Whitney, J.M. and Pagano, N.J., "Shear Deformation in Heterogeneous Anisotropic Plates," *J. Appl. Mechanics, Trans. ASME*, 37, pp 1031-1036 (1970).
15. Fortier, R.C. and Rossettos, J.N., "On the Vibration of Shear Deformable Curved Anisotropic Composite Plates," *J. Appl. Mech., Trans. ASME*, 40, pp 299-301 (1973).
16. Sinha, P.K. and Rath, A.K., "Vibration and Buckling of Cross-Ply Laminated Circular Cylindrical Panels," *Aeronaut. Quart.*, 26, pp 211-218 (1975).
17. Bert, C.W. and Chen, T.L.C., "Effect of Shear Deformation on Vibration of Antisymmetric Angle-Ply Laminated Rectangular Plates," *Intl. J. Solids Struc.*, 14, pp 465-473 (1978).
18. Pryor, C.W., Jr. and Barker, R.M., "A Finite Element Analysis Including Transverse Shear Effects for Applications to Laminated Plates," *AIAA J.*, 9, pp 912-917 (1971).
19. Barker, R.M., Lin, F.T., and Dana, J.R., "Three Dimensional Finite-Element Analysis of Laminated Composites," *Natl. Symp. Computerized Structural Anal. Des.*, George Washington Univ. (1972).
20. Mau, S.T., Tong, P., and Pian, T.H.H., "Finite Element Solutions for Laminated Thick Plates," *J. Composite Matls.*, 6, pp 304-311 (1972).
21. Mau, S.T., Pian, T.H.H., and Tong, P., "Vibration Analysis of Laminated Plates and Shells by a Hybrid Stress Element," *AIAA J.*, 11, pp 1450-1452 (1973).
22. Noor, A.K., "Free Vibrations of Multilayered Composite Plates," *AIAA J.*, 11, pp 1038-1039 (1973).
23. Noor, A.K. and Mathers, M.D., "Anisotropy and Shear Deformation in Laminated Composite Plates," *AIAA J.*, 14, pp 282-285 (1976).
24. Noor, A.K. and Mathers, M.D., "Finite Element Analysis of Anisotropic Plates," *Intl. J. Numer. Methods Engr.*, 11, pp 289-307 (1977).
25. Hinton, E., "A Note on a Thick Finite Strip Method for the Free Vibration of Laminated Plates," *Intl. J. Earthquake Engr. Struct. Dynam.*, 4, pp 511-514 (1976).
26. Mawenya, A.S. and Davies, J.D., "Finite Element Bending Analysis of Multilayer Plates," *Intl. J. Numer. Methods Engr.*, 8, pp 215-225 (1974).

27. Panda, S.C. and Natarajan, R., "Finite Element Analysis of Laminated Composite Plates," *Intl. J. Numer. Methods Engr.*, 14, pp 69-79 (1979).
28. Ahmad, S., Irons, B.M., and Zienkiewicz, O.C., "Analysis of Thick and Thin Shell Structures by Curved Finite Elements," *Intl. J. Numer. Methods Engr.*, 2, pp 419-451 (1970).
29. Spilker, R.L., Chou, S.C., and Orringer, O., "Alternate Hybrid Stress Elements for Analysis of Multilayer Composite Plates," *J. Composite Mats.*, 11, pp 51-70 (1977).
30. Reddy, J.N., "A Penalty Plate-Bending Element for the Analysis of Laminated Anisotropic Composite Plates," *Intl. J. Numer. Methods Engr.*, 15, pp 1187-1206 (1980).
31. Reddy, J.N. and Chao, W.C., "A Comparison of Closed-Form and Finite Element Solutions of Thick Laminated Anisotropic Rectangular Plates," *Nuclear Engr. Des.*, 64 (1981).
32. Reddy, J.N., "Free Vibration of Antisymmetric, Angle-Ply Laminated Plates, Including Transverse Shear Deformation by the Finite Element Method," *J. Sound Vib.*, 66 (4), pp 565-576 (1979).
33. Reddy, J.N. and Bert, C.W., "Analyses of Plates Constructed of Fiber-Reinforced Bimodulus Materials," *Mechanics of Bimodulus Materials*, (Bert, C.W., Ed.), AMD Vol. 33, ASME, pp 29-37 (1979).
34. Reddy, J.N. and Chao, W.C., "Finite-element Analysis of Laminated Bimodulus Composite-Material Plates," *Computers Struc.*, 12, pp 245-251 (1980).
35. Whitney, J.M. and Leissa, A.W., "Analysis of Heterogeneous Anisotropic Plates," *J. Appl. Mechanics, Trans. ASME*, 36, pp 261-266 (1969).
36. Bennett, J.A., "Nonlinear Vibration of Simply Supported Angle Ply Laminated Plates," *AIAA J.*, 9, pp 1997-2003 (1971).
37. Bert, C.W., "Nonlinear Vibration of a Rectangular Plate Arbitrarily Laminated of Anisotropic Material," *J. Appl. Mechanics, Trans. ASME*, 40, pp 452-458 (1973).
38. Chandra, R. and Raju, B.B., "Large Amplitude Flexural Vibration of Cross-Ply Laminated Composite Plates," *Fibre Sci. Tech.*, 8, pp 243-263 (1975).
39. Chandra, R., "Large Deflection Vibration of Cross-Ply Laminated Plates with Certain Edge Conditions," *J. Sound Vib.*, 47 (4), pp 509-514 (1976).
40. Zaghoul, S.A. and Kennedy, J.B., "Nonlinear Analysis of Unsymmetrically Laminated Plates," *ASCE J. Engr. Mechanics Div.*, 101 (EM3), pp 169-185 (1975).
41. Chia, C.Y. and Prabhakara, M.K., "Large Deflection of Unsymmetric Cross-Ply and Angle-Ply Plates," *J. Mech. Engr. Sci.*, 18 (4), pp 179-183 (1976).
42. Chia, C.Y. and Prabhakara, M.K., "A General Mode Approach to Nonlinear Flexural Vibrations of Laminated Rectangular Plates," *J. Appl. Mechanics, Trans. ASME*, 45, pp 623-628 (1978).
43. Noor, A.K. and Hartley, S.J., "Effect of Shear Deformation and Anisotropy on the Non-Linear Response of Composite Plates," *Developments in Composite Materials - 1*, (Holister, G., Ed.), Appl. Sci. Publ., Barking, Essex, England, pp 55-65 (1977).
44. Reddy, J.N. and Chao, W.C., "Large Deflection and Large Amplitude Free Vibrations of Laminated Composite Material Plates," *Computers Struc.*, 13 (2), pp 341-347 (1981).
45. Reddy, J.N. and Chao, W.C., "Non-Linear Bending of Thick Rectangular, Laminated Composite Plates," *Intl. J. Nonlin. Mechanics* (1981).
46. Ambartsumyan, S.A., *Theory of Anisotropic Plates* (English Translation), Technomic, Stamford, CT (1970).

47. Hassert, J.E. and Nowinski, J.L., "Nonlinear Transverse Vibration of a Flat Rectangular Orthotropic Plate Supported by Stiff Rig," Proc. 5th Intl. Symp. Space Tech. Sci., Tokyo, pp 561-570 (1962).
48. Nowinski, J.L., "Nonlinear Vibrations of Elastic Circular Plates Exhibiting Rectilinear Orthotropy, Z. Angew. Meth. Physik, 14, pp 112-124 (1963).
49. Nowinski, J.L. and Ismail, I.A., "Large Oscillations of an Anisotropic Triangular Plate," J. Franklin Inst., 280, pp 417-424 (1965).
50. Wu, C.I. and Vinson, J.R., "On the Nonlinear Oscillations of Plates Composed of Composite Materials," J. Composite Matls., 3, pp 548-561 (1969).
51. Mayberry, B.L. and Bert, C.W., "Experimental Investigation of Nonlinear Vibrations of Laminated Anisotropic Panels, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 39, Pt 3, pp 191-199 (1969).
52. Nowinski, J.L., "Nonlinear Oscillations of Anisotropic Plates under Large Initial Stress," Proc. 10th Cong. Theoret. Appl. Mechanics, Madras, India, pp 13-30 (1965).
53. Sathyamoorthy, M. and Pandalai, K.A., "Nonlinear Flexural Vibrations of Orthotropic Rectangular Plates," J. Aeronaut. Soc. India, 22, pp 264-266 (1970).
54. Prabhakara, M.K. and Chia, C.Y., "Nonlinear Flexural Vibrations of Orthotropic Rectangular Plates," J. Sound Vib., 52, pp 511-518 (1977).
55. Sathyamoorthy, M. and Chia, C.Y., "Nonlinear Vibration of Anisotropic Rectangular Plates Including Shear and Rotatory Inertia," Fibre Sci. Tech., 13, pp 337-361 (1980).
56. Sathyamoorthy, M. and Chia, C.Y., "Effect of Transverse Shear and Rotatory Inertia on Large Amplitude Vibration of Anisotropic Skew Plates; Part 1: Theory," J. Appl. Mechanics, Trans. ASME, 47, pp 128-132 (1980).
57. Sathyamoorthy, M. and Chia, C.Y., "Effect of Transverse Shear and Rotatory Inertia on Large Amplitude Vibration of Anisotropic Skew Plates; Part 2: Numerical Results," J. Appl. Mechanics, Trans. ASME, 47, pp 133-138 (1980).
58. Wu, C.I. and Vinson, J.R., "Nonlinear Oscillations of Laminated Specially Orthotropic Plates with Clamped and Simply Supported Edges," J. Acoust. Soc. Amer., 49, pp 1561-1567 (1971).
59. Chandra, R. and Basava Raju, B., "Large Deflection Vibration of Angle Ply Laminated Plates," J. Sound Vib., 40, pp 393-408 (1975).
60. Reddy, J.N., "Nonlinear Vibration of Layered Composite Plates Including Transverse Shear and Rotatory Inertia," 1981 ASME Vib. Conf., Hartford, CT (Sept 20-23, 1981).
61. Reddy, J.N., "Analysis of Layered Composite Plates Accounting for Large Deflections and Transverse Shear Strains," Recent Advances in Nonlinear Computational Mechanics (E. Hinton et al., Eds.), Pineridge Press, Swansea, United Kingdom (to appear).
62. Reddy, J.N. and Chao, W.C., "Nonlinear Oscillations of Laminated Anisotropic, Thick, Rectangular Plates," Struc. Matls. Conf., 1981 Winter Ann. Mtg. ASME, Washington, DC.
63. Bert, C.W., "Dynamics of Composite and Sandwich Panels," Part I, Shock Vib. Dig., 8 (10), pp 37-48 (Oct 1976).
64. Bert, C.W., "Dynamics of Composite and Sandwich Panels," Part II, Shock Vib. Dig., 8 (11), pp 15-24 (Nov 1976).
65. Bert, C.W., "Vibration of Composite Structures," Proc. Intl. Conf. Recent Advances Struc. Dynam., Univ. of Southampton, Southampton, England (July 7-11, 1980).
66. Reddy, J.N., "Finite Element Modeling of Structural Vibrations: A Review of Recent Advances," Shock Vib. Dig., 11 (1), pp 25-39 (Jan 1979).

67. Leissa, A.W., "Advances in Vibration, Buckling and Postbuckling Studies on Composite Plates," Intl. Conf. Composite Struc., Paisley, Scotland (Sept 16-18, 1981).
68. Ambartsumyan, S.A., "Calculation of Laminated Anisotropic Shells," *Izvestiia Akademii Nauk Armenskoi SSR, Ser. Fiz. Mat. Est. Tekh. Nauk.*, 6 (3), p 15 (1953).
69. Ambartsumyan, S.A., *Theory of Anisotropic Shells*. Moscow, 1961; English translation, NASA TT F-118 (May 1964).
70. Dong, S.B., Pister, K.S., and Taylor, R.L., "On the Theory of Laminated Anisotropic Shells and Plates," *J. Aerospace Sci.*, 29, pp 969-975 (1962).
71. Stavsky, Y., "Bending and Stretching of Laminated Anisotropic Plates," *ASCE J. Engr. Mechanics Div.*, 87 (EM6), p 31 (1961).
72. Love, A.E.H., "On the Small Free Vibrations and Deformations of the Elastic Shells," *Philosoph. Trans. Royal Soc. (London), Ser. A*, 17, pp 491-546 (1888).
73. Cheng, S. and Ho, B.P.C., "Stability of Heterogeneous Anisotropic Cylindrical Shells under Combined Loading," *J. Amer. Inst. Aeronaut. Astronaut.*, 1 (4), pp 892-898 (1963).
74. Flugge, W., *Stresses in Shells*. Springer-Verlag, Berlin (1960).
75. Bert, C.W., "Structural Theory for Laminated Anisotropic Elastic Shells," *J. Composite Matls.*, 1, pp 414-423 (1967).
76. Vlasov, V.Z., *General Theory of Shells and Its Applications in Engineering*, Moscow, 1949; English Translation, NASA TT F-99 (1964).
77. Widera, O.E. and Chung, S.W., "A Theory for Non-Homogeneous Anisotropic Cylindrical Shells," *Z. Angew Math. Physik*, 21, pp 378-399 (1970).
78. Donnell, L.H., "Stability of Thin Walled Tubes in Torsion," *NACA Rep.* 479 (1933).
79. Bert, C.W., "Analysis of Shells," *Analysis of Performance of Composites*, (Broutman, L.G., Ed.), Wiley, NY, Ch. 5, pp 207-258 (1980).
80. Zukas, J.A. and Vinson, J.R., "Laminated Transversely Isotropic Cylindrical Shells," *J. Appl. Mechanics, Trans. ASME*, pp 400-407 (1971).
81. Dong, S.B. and Tso, F.K.W., "On a Laminated Orthotropic Shell Theory Including Transverse Shear Deformation," *J. Appl. Mechanics, Trans. ASME*, 39, pp 1091-1097 (1972).
82. Whitney, J.M. and Sun, C.T., "A Refined Theory for Laminated Anisotropic, Cylindrical Shells," *J. Appl. Mechanics*, 41, pp 471-476 (1974).
83. Widera, G.E.O. and Logan, D.L., "Refined Theories for Nonhomogeneous Anisotropic Cylindrical Shells; Part I: Derivation," *ASCE J. Engr. Mechanics Div.*, 106 (EM6), pp 1053-1074 (1980).
84. Logan, D.L. and Widera, G.E.O., "Refined Theories for Nonhomogeneous Anisotropic Cylindrical Shells; Part II: Application," *ASCE J. Engr. Mechanics Div.*, 106 (EM6), pp 1075-1090 (1980).
85. Dong, S.B., "Analysis of Laminated Shells of Revolution," *ASCE J. Engr. Mechanics Div.*, 92 (EM6), p 135 (1966).
86. Dong, S.B. and Selna, L.G., "Natural Vibrations of Laminated Orthotropic Shells of Revolution," *J. Composite Matls.*, 4 (1), pp 2-19 (1970).
87. Wilson, E.A. and Parsons, B., "The Finite Element Analysis of Filament-Reinforced Axisymmetric Bodies," *Fibre Sci. Tech.*, 2, pp 155-156 (1969).
88. Schmit, L.A. and Monforton, G.R., "Finite Element Analysis of Sandwich Plate and Laminate Shells with Laminated Faces," *J. Amer. Inst. Aeronaut. Astronaut.*, 8, pp 1454-1461 (1970).

89. Thompson, G.L., "Finite-Element Analysis for Free Vibration of General Anisotropic Laminated Thin Shells," *Composite Materials in Engineering Design* (Proc. 6th St. Louis Symp., May 1972), (Noton, B.R., Ed.), ASM (1973).
90. Padavon, J., "Quasi-Analytical Finite Element Procedures for Axisymmetric Anisotropic Shells and Solids," *Computers Struc.*, 4, pp 467-483 (1974).
91. Padavon, J., "Numerical Analysis of Asymmetric Frequency and Buckling Eigenvalues of Prestressed Rotating Anisotropic Shells of Revolution," *Computers Struc.*, 5, pp 145-154 (1975).
92. Padavon, J., "Travelling Waves Vibrations and Buckling of Rotating Anisotropic Shells of Revolution by Finite Elements," *Intl. J. Solids Struc.*, 11, pp 1367-1380 (1975).
93. Noor, A.K. and Mathers, M.D., "Shear-Flexible Finite-Element Models of Laminated Composite Plates and Shells," NASA TN D-8044, Langley Res. Ctr., Hampton, VA.
94. Noor, A.K. and Camin, R.A., "Symmetry Considerations for Anisotropic Shells," *Computer Methods Appl. Mechanics Engr.*, 9, pp 317-335 (1976).
95. Noor, A.K. and Andersen, C.M., "Mixed Isoparametric Finite Element Models of Laminated Composite Shells," *Computer Methods Appl. Mechanics Engr.*, 11 (3), pp 255-280 (1977).
96. Panda, S.C. and Natarajan, R., "Finite Element Analysis of Laminated Shells of Revolution," *Computers Struc.*, 6, pp 61-64 (1976).
97. Shivakumar, K.N. and Krishna Murty, A.V., "A High Precision Ring Element for Vibrations of Laminated Shells," *J. Sound Vib.*, 58 (3), pp 311-318 (1978).
98. Rao, K.P., "A Rectangular Laminated Anisotropic Shallow Thin Shell Finite Element," *Computer Methods Appl. Mechanics Engr.*, 15, pp 13-33 (1978).
99. Siede, P. and Chang, P.H.H., "Finite Element Analysis of Laminated Plates and Shells," NASA CR-157106 (1978).
100. Hsu, Y.S., Reddy, J.N., and Bert, C.W., "Thermoelasticity of Circular Cylindrical Shells Laminated of Bimodulus Composite Materials," *J. Thermal Stresses*, 4 (2) (1981).
101. Noor, A.K. and Hartley, S.J., "Nonlinear Shell Analysis via Mixed Isoparametric Elements," *Computers Struc.*, 7, pp 615-626 (1977).
102. Chang, T.Y. and Sawamiphakdi, K., "Large Deformation Analysis of Laminated Shells by Finite Element Method," *Computers Struc.*, 13, pp 331-340 (1981).
103. Reddy, J.N., "A Finite-Element Analysis of Large-Deflection Bending of Laminated Anisotropic Shells," *Symp. Nonlin. Finite-Element Analysis Shells*, 1981 Winter Ann. Mtg. ASME, Washington, DC (Nov 15-20, 1981).
104. Sanders, J.L., Jr., "An Improved First Approximation Theory for Thin Shells," NASA TR R-24 (June 1959).
105. Loo, T.T., "An Extension of Donnell's Equation for a Circular Cylindrical Shell," *J. Aeronaut. Sci.*, 24, pp 390-391 (1957).
106. Morley, L.S.D., "An Improvement of Donnell's Approximation of Thin-Walled Circular Cylinders," *Quart. J. Mech. Appl. Math.*, 8, pp 87-99 (1959).
107. Hayashi, T., "Analytical Study of Interlaminar Shear Stresses in a Laminated Composite Plate," *Trans. Japan Soc. Aero. Engr. Space Sci.*, 10 (47), p 43 (1967).
108. Pagano, N.J., "Stress Fields in Composite Laminates," *Intl. J. Solids Struc.*, 14, pp 385-400 (1978).
109. Pagano, N.J., "Free Edge Stress Fields in Composite Laminates," *Intl. J. Solids Struc.*, 14, pp 401-406 (1978).
110. Wang, A.S.D. and Crossman, F.W., "Some New Results on Edge Effect in Symmetric

- Composite Laminates, *J. Composite Matls.*, 8, pp 92-106 (1977).
111. Salamon, N.J., "Interlaminar Stresses in a Layered Composite Laminate in Bending," *Fibre Sci. Tech.*, 11, pp 305-317 (1978).
 112. Wang, S.S. and Choi, I., "Boundary Layer Thermal Stresses in Angle-Ply Composite Laminates," *Modern Developments in Composite Materials and Structures*, (Vinson, J.R., Ed.), ASME, pp 315-341 (1979).
 113. Wang, S.S., "Edge Delamination in Angle-Ply Composite Laminates," *Proc. 22nd AIAA/ASME/SAE Struc., Struc. Dynam., Matls. Conf.*, Atlanta, GA, pp 473-484 (1981).
 114. Spilker, R.L. and Chou, S.C., "Edge Effects in Symmetric Composite Laminates: Importance of Satisfying the Traction-Free-Edge Condition," *J. Composite Matls.*, 14, pp 2-20 (1980).
 115. Raju, I.S. and Crews, J.H., Jr., "Interlaminar Stress Singularities at a Straight Free Edge in Composite Laminates," NASA Tech. Memo. 81876, Langley Res. Ctr., Hampton, VA (1980).
 116. Raju, I.S., Whitcomb, J.D., and Goree, J.G., "A New Look at Numerical Analysis of Free-Edge Stresses in Composite Laminates," NASA Tech. Paper 1751, Langley Res. Ctr., Hampton, VA (1980).
 117. Lo, K.H., Christensen, R.M., and Wu, E.M., "A Higher-Order Theory of Plate Deformation; Part 1: Homogeneous Plates," *J. Appl. Mechanics*, Trans. ASME, 44, pp 662-668 (1977).
 118. Lo, K.H., Christensen, R.M., and Wu, E.M., "A Higher-Order Theory of Plate Deformation; Part 2: Laminated Plates," *J. Appl. Mechanics*, Trans. ASME, 44, pp 669-676 (1977).
 119. Spilker, R.L., "Higher Order Three-Dimensional Hybrid-Stress Elements for Thick-Plate Analyses," *Intl. J. Numer. Methods Engr.*, 17, pp 53-69 (1981).
 120. Altus, E., Rotem, A., and Shmueli, M., "Free Edge Effect in Angle Ply Laminates - A New Three Dimensional Finite Difference Solution," *J. Composite Matls.*, 14, pp 21-30 (1980).

LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains an article about vortex shedding from cylinders and the resulting unsteady forces and flow phenomena.

Ms. S.T. Fleischmann and Professor D.W. Sallet of the University of Maryland, College Park, Maryland have written the second part of a two-part paper that presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part II introduces vortex shedding from non-circular cylinders and the topic of cylinders undergoing flow-induced vibration.

VORTEX SHEDDING FROM CYLINDERS AND THE RESULTING UNSTEADY FORCES AND FLOW PHENOMENA

PART II

S.T. Fleischmann and D.W. Sallet*

Abstract. *This two-part paper presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part II introduces vortex shedding from non-circular cylinders and the topic of cylinders undergoing flow-induced vibration. Experimental values of the unsteady lift and drag coefficients and experimental values of the Strouhal number for circular cylinders over a wide range of Reynolds numbers obtained from numerous investigators are presented.*

VORTEX SHEDDING FROM NON-CIRCULAR CYLINDERS

The preceding section treated only vortex shedding from circular cylinders. Most measurements have been made using circular cylinders, but considerable data for cylinders of non-circular cross section (that is, of other basic shapes used in structures) also exist. Attempts have been made to correlate data from other shapes with that from circular cylinders through the development of a universal Strouhal number. So that it will be applicable to all bluff bodies from which vortex shedding occurs, this universal Strouhal number is based on wake parameters rather than free-stream velocity and cylinder dimensions. Various studies of vortex shedding from cylinders of non-circular cross sections are considered and the universal Strouhal number developed by three investigators are discussed below.

Knauss, John, and Marks [51] studied vortex shedding from elliptical cylinders having small eccentricity and from square cylinders at various angles of attack in the low Reynolds number range ($300 \leq Re \leq 1200$). It should be noted that the results from

elliptical cylinders should correspond most closely with those of circular cylinders because, as Knauss noted, the absence of a sharp edge allows the separation line to vary. For cylinders with sharp edges separation usually occurs along those edges. It was found [51] that, for elliptical cylinders with an eccentricity between 0.6 and 0.8 at zero angle of incidence, the data for $Re \leq 500$ are well represented by Roshko's relation for circular cylinders: $F = 0.212 (Re)^{-2.7}$. Above $Re = 500$, the best fit equation was a power law relationship $F = 0.27 (Re_{do})^{0.98}$ similar to Roshko's relation. For square cylinders there is a sudden drop in the Strouhal number as the angle of incidence increases beyond about 30° for various Reynolds numbers; this drop has been attributed to a detachment of the flow from the cylinder [51]. Huthloff [52] recently presented extensive measurements of the Strouhal number and the alternating lift coefficient for various cross sections, including circular cross sections, in the Reynolds numbers range of 10^4 to 10^5 . For non-circular cylinders he gave the lift coefficient and the Strouhal number as a function of angle of attack for various Reynolds numbers. He found that cylinders having square, rectangular, semicircular, or hexagonal cross sections experienced periodic forces that are considerably higher than those of circular cylinders. This is perhaps not surprising because all of the non-circular cylinders had sharp edges that would tend to define the separation line and therefore correlate the flow along the span of the cylinder. Highly correlated flow would then result in higher periodic forces. Representative results for C_L presented by Hothloff [52] are shown in Figure 11.

Lee [53] studied the effect of free-stream turbulence on vortex shedding and drag on square cylinders. He also presented a study of the effects of varying

*Department of Mechanical Engineering, The University of Maryland, College Park, MD 20742.

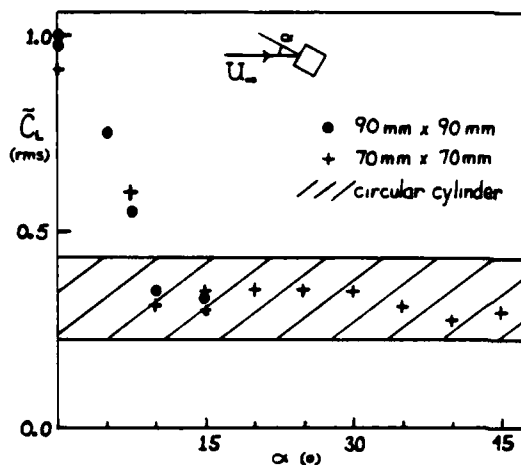


Figure 11. Representative Results [52] Showing Increased Lift Coefficient for Square Cylinders at Small Angles of Attack as Compared to Similar Results for Circular Cylinders ($4.2 \times 10^4 < Re < 1.8 \times 10^5$).

the angle of attack of square cylinders that included careful measurements of the pressure distribution on the faces of the square made with multiple, equally-spaced pressure sensors. Rockwell [32] also studied vortex shedding from square cylinders at various angles of attack and found that the low frequency modulation of the lift coefficient was due to unstable reattachment of the flow near the end of the cylinder wall

Twigg-Molecey and Baines [54] measured the Strouhal number as a function of Reynolds number for triangular cylinders in the range $9 \times 10^3 < Re < 4 \times 10^4$. They used pressure measurements on the cylinder face to obtain the periodic coefficients of lift and moment. These studies are presented as typical examples and to illustrate the general problem of vortex shedding from non-circular cylinders. The papers by Knauss [51] and Huthloff [52] contain numerous references to other work in this area.

In all of the studies mentioned (with the exception of the elliptical cross section at low Reynolds numbers) the $S = S(Re)$ relationship was found to be different from that for circular cylinders. Figure 12, which shows Roshko's data for a circular cylinder, a

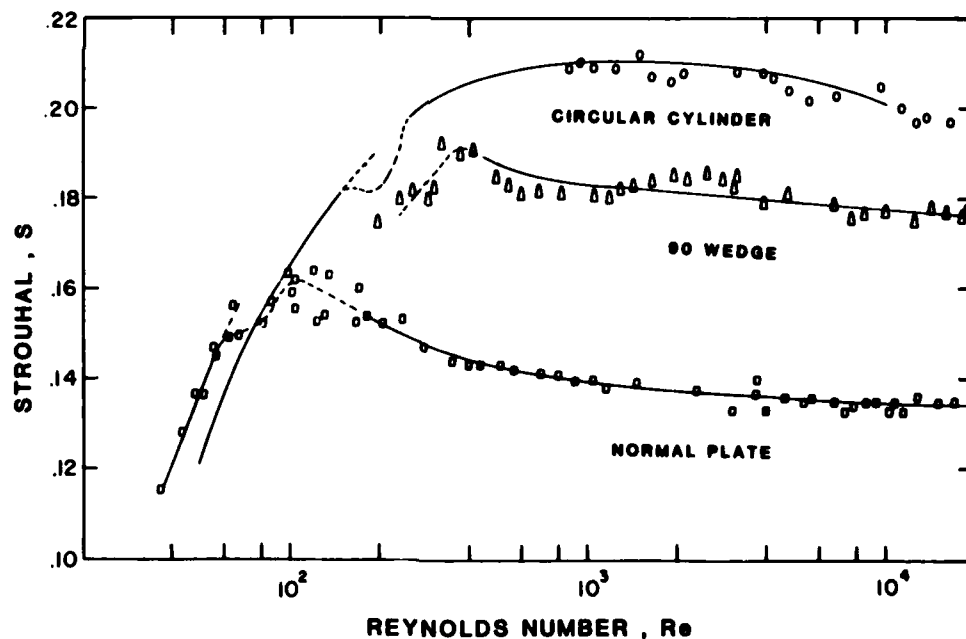


Figure 12. Roshko's Measurement of $S = S(Re)$ for Various Geometries [55].

90° wedge, and a flat plate illustrates this point. One way to correlate all of the bluff body data is to base the Strouhal number and the Reynolds number on wake parameters rather than on cylinder and upstream flow parameters. It is expected that such a Strouhal number will be universal; that is, it will apply to all bluff bodies.

In 1953, Roshko [55] found that his data for cylinders, flat plates, and 90° wedges were well correlated if they were presented using a wake Strouhal number and a wake Reynolds number. The characteristic length used in each of these numbers was h' , the separation distance of the shear layers when they become parallel. This distance was calculated using notched hodograph theory. The free stream velocity U_∞ was not used; rather, the velocity at the point of separation U_b was used where U_b was found using Bernoulli's equation and the measured base pressure coefficient C_{bp} .

$$\frac{U_b}{U_\infty} = (1 - C_{bp})^{1/2}$$

Roshko's wake Strouhal number is

$$S^* = \frac{fh'}{U_b} = S \frac{U_\infty}{U_b} \frac{h'}{d}$$

and his wake Reynolds number is

$$Re^* = \frac{U_b h'}{\nu} = Re \frac{h' U_b}{d U_\infty}$$

where d is the cylinder dimension and Re and S are the usual Reynolds number and Strouhal number based on free-stream velocity and cylinder dimensions. Roshko's results using the wake parameters discussed are shown in Figure 13; the good correlation is evident.

Bearman [56] later noted that Roshko's formulation assumes that the vortices form from shear layers at the spacing predicted by notched hodograph theory. He further noted that, in such cases as near-wake interference, the commencement of vortex shedding is delayed to a point downstream of the cylinder and that the separation of the shear layers

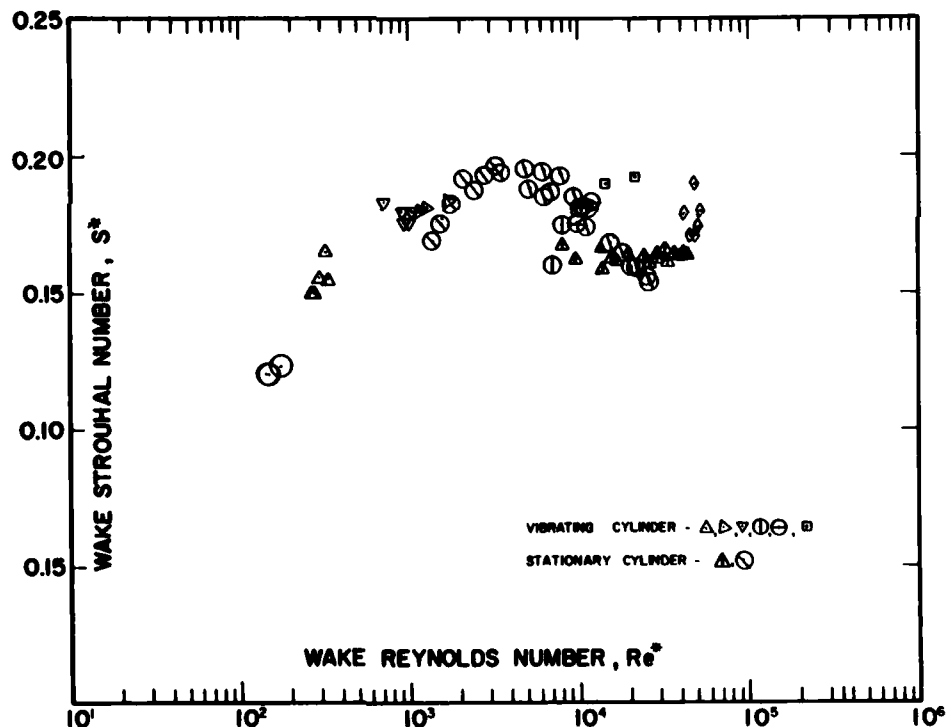


Figure 13. Wake Strouhal Number vs. Wake Reynolds Number. For stationary cylinders [54]: Δ , triangular cross section-Roshko; \odot , circular cylinder-Roshko; for vibrating cylinders [56]: Δ , Griffin and Ramberg-1974; \triangleright , Griffin et al-1973; ∇ , Griffin and Ramberg-1976; \oplus , Tanida et al-1973; \ominus , Stansby-1976; \square , Meyers-1975; \odot , Tanida et al-1973.

at that point is not equal to the shear layer separation obtained from notched hodograph theory. Bearman then defined a new universal Strouhal number based on the distance h'' between the shear layer at the commencement of vortex shedding. This distance h'' is equal to the lateral spacing h in the vortex street. Bearman's universal Strouhal number is defined as:

$$S_B = \frac{fh}{U_b} = \frac{Sh}{d} \frac{U_\infty}{U_b}$$

The ratio $\frac{h}{d}$ can be found using the stability criterion proposed by either von Karman ($h/\ell = .281$) or Kronauer

$$\left. \frac{\partial C_D}{\partial (h/\ell)} \right|_{\frac{U_S}{U_\infty}} = 0$$

C_D is Karman's analytical expression. Bearman found the best correlation by using the Kronauer stability criterion to determine $\frac{h}{d}$; the shedding frequency and base pressure coefficient were experimentally obtained.

Both Roshko's and Bearman's formulations apply to stationary cylinders. Griffin [57] recently extended the concept of the universal Strouhal number to the case of freely vibrating cylinders. In his formulation the length parameter h' was the measured distance between the shear layers at the end of the vortex formation region. His results using his own data and the data of other investigators are given in Figure 13; there is good agreement with results for stationary cylinders of various cross sections.

VIBRATING CYLINDERS

The periodic forces due to vortex shedding from a cylinder in cross flow and the various flow regimes for a rigidly supported circular cylinder – that is, a cylinder for which the flow-cylinder interaction is restrained – have been described. The question now arises: what happens when flow-cylinder interaction is allowed and the cylinder vibrates. The question is relevant to all disciplines of engineering because costly structural damage can occur due to vortex-induced resonant motions of elastically-supported structural members; more knowledge in this area is needed.

Berger and Willie [37] reviewed the work in vibrating cylinders up to 1972 and Mair and Maull [40] reported on results presented at Euromech 17. Brief introductory reviews of more recent work are available [58, 59]. A scheme for the classification and analysis of flow-induced vibration problems has been given [60]. Numerous conferences concerning flow-induced vibrations in the past 10 years attest to the continued research interest in this problem [61-65]. This section considers flow-induced cylinder vibration; emphasis is on the physical processes involved.

It should be noted that the flow-cylinder interaction is extremely complex and highly nonlinear. The motion of the cylinder changes the geometry of the vortex wake and the periodic fluid forces on the cylinder. In turn, the changes in the periodic forces change the cylinder motion. Because the flow-cylinder interaction is so complex, results obtained from experiments in which the frequency and amplitude of vibration are externally controlled are often applied to the case of flow-induced vibration. Such applications must be done very carefully. Griffin [66] has shown that the near wake and the phase relation between the flow field and the cylinder motion are essentially the same for cylinders under forced and flow-induced vibrations if the Reynold's number and the frequency and amplitude of vibration are matched.

For small amplitude vibrations increased span-wise correlation in flow has been reported [24, 37, 67]. The increased span-wise correlation makes the flow more strongly two-dimensional and therefore increases the lift force on the cylinder. In experiments on forced vibrating cylinders Griffin and Ramberg [30] noted that when the ratio of vibration amplitude to cylinder diameter, a/d , is less than 50% (within the range of observed resonant response to flow-induced vibrations) the circulation of the vortices increases and the length of formation decreases. Bearman [56] found a nearly inverse relation between the base pressure coefficient (and therefore the drag) and the length of formation. Increased steady drag for a vibrating cylinder has been observed.

When the vortex shedding frequency is sufficiently close to the natural frequency of an elastically mounted cylinder or structural member, the vortex

shedding frequency, f , and the natural frequency become synchronized; that is, the Strouhal frequency, f_s , is suppressed and for a range of Reynold's numbers the shedding frequency is equal to the natural frequency of the cylinder system. This phenomenon is known as lock-in or wake capture. It is under conditions of lock-in that large amplitude resonant vibrations are observed.

Umemura, Yamaguchi, and Shiraki [68] used a spring mounted circular cylinder to investigate the amplitude response and the limits of lock-in as a function of external damping. They presented the amplitude response and the frequency of vortex shedding for the same cylinder under three different conditions of damping. For the highly damped system they found that almost no lock-in occurred. When damping was decreased by about an order of magnitude, lock-in occurred when the Strouhal frequency reached the system's natural frequency and persisted over a short range of higher Reynold's numbers, after which the shedding frequency abruptly returned to the Strouhal frequency. When the damping was decreased by yet another order of magnitude, lock-in occurred over the entire range of Reynold's numbers tested, both below and above V^* , the free-stream velocity for which the Strouhal and natural frequencies are equal. The maximum amplitude of vibration increased by roughly an order of magnitude each time the damping was decreased by about an order of magnitude. Furthermore the flow speed at which the maximum amplitude occurred increased with decreased external damping.

Although the flow speed, V_{max} , for which the maximum amplitude occurred was different for the three cases quoted, and the maximum amplitude was different, the flow speed range over which pronounced resonant vibration occurred relative to V_{max} seemed to be about the same (± 1 m/sec) in all cases. For cases of high and medium damping the vibration built up and died down outside the region of lock-in, but the maximum amplitude of vibration occurred in the region of lock-in.

Feng and Parkinson [69], in experiments with spring mounted cylinders of circular and D-section, observed similar behavior in their investigation of lock-in for the case of the circular cylinder. They also found that the free-stream velocity for which the maximum amplitude was attained was lower

when the velocity was gradually decreased than when it was gradually increased through the lock-in region. Feng and Parkinson [69] also observed that, while lock-in occurred mostly above V^* for circular cylinders, it occurred mostly below V^* for the D-section cylinders.

All cylinders experience fluid damping in addition to external mechanical damping. Griffin and Koopmann [59] reported a rapid decrease in fluid damping just before lock-in and a rapid increase immediately thereafter. Skop, Ramberg, and Ferer [70] have discussed the measurement and evaluation of fluid damping and added mass.

The amplitude and frequency response of spring mounted and externally damped cylinders that were free to vibrate perpendicular to the flow direction in water have been studied by Meier-Windhorst [71]. Similar results for spring mounted cylinders in air have been obtained by Glass [72] and others [58, 59]. Toebes and Eagleston [73] showed experimentally that the amplitude response of non-circular bluff bodies depends in general on the trailing edge geometry.

Throughout the lock-in region (with the exception of possibly one point) the shedding frequency is different from the Strouhal frequency observed for stationary cylinders. Because the shedding frequency is different, the longitudinal spacing of the wake vortices will also be different from that in the wake of stationary cylinders. In an extension of the two-dimensional Karman model to cylinders under small amplitude vibrations Sallet [14] noted that, for constant lateral spacing, an increase in longitudinal spacing leads to an increase in lift and vice versa. The Karman model also shows that, at constant longitudinal spacing (shedding frequency), changes in lateral spacing change the lift. In observations of cylinders under forced vibration Griffin and Ramberg [30] confirmed earlier observations [28] that, at constant vibration frequency, an increase in cylinder amplitude results in a decrease in lateral vortex spacing and that, at constant amplitude, the longitudinal spacing varies inversely with vibration frequency. The lateral spacing for a cylinder forced to vibrate at 85% of the Strouhal frequency approached zero as a/d approached 0.5 [30]. Further increases in the amplitude caused serious distortions of the wake. For vibration frequencies closer to the Strou-

hal frequency the critical vibration amplitude for which serious disorders in the wake first appeared also increased. It is possible that the approach to zero lateral spacing poses a limit to the amplitude of flow-induced vibration.

In accord with the observed resonant amplitude response of an elastically-supported cylinder under conditions of lock-in, Griffin and Koopmann [59] showed that the coefficient of lift increases to a maximum of $C_L^* = 0.5$ to 0.6 and then gradually decreases as the Reynolds number is slowly increased through the region of lock-in. Bishop and Hassan [74] showed that C_L^* for a vibrating cylinder is greater than C_L for a stationary cylinder before the maximum amplitude is reached and that C_L^* was less than C_L afterward.

Griffin, Skop, and Koopmann [58] noted that the energy transfer from the fluid to the cylinder is positive when the lift force has a component in phase with the cylinder motion. They used measurements to show that maximum energy transfer occurs when the maximum amplitude is obtained. It has been reported [58, 59, 74, 75] that a phase shift of about 90° occurs as the lock-in region is traversed; i.e., a phase shift of cylinder motion relative to the lift force.

The amplitude response of a cylinder in cross flow is evidently complex. The most successful model of cylinder motion has been the wake oscillator model, which was introduced by Hartlan and Currie [76] and further developed by Skop and Griffin [77]. An introduction to the model and further references are available [2, 3, 58, 59].

The focus of this paper has been the periodic forces on a cylinder in cross flow. Not only do the periodic forces due to cylinder vibration change but the steady drag force is also increased. Sallet [14] in his extension of the Karman model to vibrating cylinders noted a general trend to increased steady drag as cylinder amplitude increases. Tanida, Okajima, and Watanabe [78] have measured the increased drag experienced by a forced vibrating circular cylinder that was towed through water. Griffin, Skop, and Koopmann [58] measured an increased steady drag for freely vibrating cylinders. Griffin and Ramberg [30] found an inverse relation between the length of formation and the steady drag and reported

increased steady drag when the cylinder vibrates. Additional information is available [3].

Both the periodic forces and the steady forces change radically as a cylinder vibrates; flow-cylinder interaction is extremely complex. The topic of flow-induced vibrations is a topic of current research and much work remains in this area.

ACKNOWLEDGMENT

The authors wish to acknowledge the Minta Martin committee at the University of Maryland for their support during the writing of this paper and for their continuing support of further research in this area.

REFERENCES

1. Chen, S.S., "Flow-induced Vibrations of Circular Cylindrical Structures. Part I: Stationary Fluids and Parallel Flow," *Shock Vib. Dig.*, 9 (10), pp 25-38 (Oct 1977).
2. Chen, S.S., "Flow-induced Vibrations of Circular Cylindrical Structures. Part II: Cross-flow Considerations," *Shock Vib. Dig.*, 9 (11), pp 21-27 (Nov 1977).
3. Blevins, R.D., *Flow-induced Vibration*, Von Nostrand Reinhold (1977).
4. Rubach, H.L., "Ueber die Entstehung und Fortbewegung des Wirbelpaares hinter zylindrischen Körpern," *Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Verein Deutscher Ingenieure*, Heft 185, Berlin (1916).
5. Foppl, L., "Wirbelbewegung hinter einem Kreis-zylinder," *Sitzungsberichte der mathematisch-physikalischen Klasse der Königlich Bayerischen Akademie der Wissenschaften*, München, pp 1-17 (1913).
6. Strouhal, V., "Über Eine Besondere Art der Tonnerregung," *Ann. Phys. Chemie, Neue Folge*, Bd. 5, Heft 10, pp 216-251 (Oct 1878).
7. von Karman, T. and Rubach, H., "Über den Mechanismus des Flüssigkeits und Luftwider-

- standes," *Physikalische Zeitschrift*, 13 (2), pp 49-59 (Jan 1912).
8. Bernard, H., "Formation de Centres de Giration à l'arrière d'un Obstacle en Mouvement," *Comp. Rend., Acad. Sci. (Paris)*, 147, pp 839-842 (Nov 9, 1908).
 9. von Kármán, T., "Über den Mechanismus des Widerstandes den ein bewegter Körper in einer Flüssigkeit erfährt," *Nachrichten der K. Gesellschaft der Wissenschaften zu Göttingen; Mathematisch-Physikalische Klasse*, pp 509-517 (1911).
 10. *Ibid.*, pp 547-556 (1912).
 11. Krzywoblocki, M.Z., "Vortex Streets in Fluids," *Applied Mechanics Surveys*, edited by H. Horman Abramson, Harold Leibowitz et. al., Spartan Books, pp 885-892 (1966).
 12. Sallet, D.W., "On the Prediction of Flutter Forces," *Contribution to Flow-Induced Structural Vibrations*, E. Naudascher, editor (Symp., Karlsruhe, Germany, Aug 1972) Springer Verlag, pp 159-176.
 13. Sallet, D.W., "The Lift Force due to von Kármán's Vortex Wake," *J. Hydronautics*, 7 (4), pp 161-165 (Oct 1973).
 14. Sallet, D., "The Drag and Oscillating Transverse Force on Vibrating Cylinders due to Steady Fluid Flow," *Ing. Arch.*, 44, pp 113-122 (1975).
 15. Sallet, D., "On the Spacing of Kármán Vortices," *J. Appl. Mechanics*, *Trans. ASME*, pp 370-372 (June 1969).
 16. Bearman, P.W., "On Vortex Street Wakes," *J. Fluid Mechanics*, 28, pt 4, pp 625-641 (1967).
 17. Griffin, O., "On Vortex Strength and Drag in Bluff-Body Wakes," *J. Fluid Mechanics*, 69, pt 4, pp 721-728 (1975).
 18. Jendrzeczyk, J.A. and Chen, S.S., "Fluid Forces Acting on Circular Cylinders in Liquid Cross-flow," *Tech. Mem. ANL-CT-81-13*, Argonne Nat'l Lab. (Dec 1980).
 19. Keefe, R.T., "Investigation of the Fluctuating Forces Acting on a Circular Cylinder in a Subsonic Stream and the Associated Sound Field," *J. Acoust. Soc. Amer.*, 34 (11), pp 1711-1714 (Nov 1962).
 20. Okamoto, T. and Yagita, M., "The Experimental Investigation on the Flow Past a Circular Cylinder of Finite Length Placed Normal to the Plane Surface in a Uniform Stream," *Bull. JSME*, 16 (95), pp 805-814 (May 1973).
 21. Humphreys, J.S., "On a Circular Cylinder in a Steady Wind at Transition Reynolds Numbers," *J. Fluid Mechanics*, 9, pt 4, pp 603-612 (1960).
 22. Hussain, AKMF and Ramjee, V., "Periodic Wake Behind a Circular Cylinder at Low Reynolds Numbers," *Aeronaut. Quart.*, 27, pt 2, pp 123-142 (May 1976).
 23. Schubauer, G.B. and Skramstad, H.K., "Laminar Boundary-Layer Oscillations and Transition on a Flat Plate," *NACA Rep. 909* (1943).
 24. Toeves, G.H., "The Unsteady Flow and Wake Near an Oscillating Cylinder," *J. Basic Engr.*, pp 493-505 (Sept 1969).
 25. Griffin, O.M., "Flow near Self-Excited and Forced Vibrating Cylinders," *J. Engr. Indus., Trans. ASME*, pp 539-547 (May 1972).
 26. Gaster, M., "Vortex Shedding from Slender Cones," *J. Fluid Mechanics*, 38, pt 3, pp 565-576 (1969).
 27. Umemura, S., Yamaguchi, T., and Shirahi, K., "On the Vibration of Cylinders Caused by Karman Vortex," *Bull. JSME*, 14 (75), pp 929-937 (1971).
 28. Koopmann, G.H., "The Vortex Wakes of Vibrating Cylinders at Low Reynolds Numbers," *J. Fluid Mechanics*, 28, pp 501-512 (1967).
 29. Griffin, O.M. and Votaw, C.W., "The Vortex Street in the Wake of a Vibrating Cylinder," *J. Fluid Mechanics*, 55, pp 31-48 (1972).
 30. Griffin, O.M. and Ramberg, S.E., "The Vortex Street Wakes of Vibrating Cylinders," *J. Fluid Mechanics*, 66, pt 3, pp 553-576 (1974).

31. Thomas, D.G. and Kraus, K.A., "Interaction of Vortex Streets," *J. Appl. Physics*, 35 (12), pp 3458-3459 (Dec 1964).
32. Rockwell, D.O., "Organized Fluctuations due to Flow Past a Square Cross-Section Cylinder," *J. Fluids Engr., Trans. ASME*, 99 (3), pp 511-516 (Sept 1977).
33. Roshko, A., "On the Development of Turbulent Wakes from Vortex Streets," *NACA Tech. Note* 2913 (Mar 1953).
34. Nishioha, M. and Sato, H., "Mechanism of Determination of the Shedding Frequency of Vortices behind a Cylinder at Low Reynolds Numbers," *J. Fluid Mechanics*, 89, pt 1, pp 49-60.
35. Goldstein, S. (Ed), *Modern Developments in Fluid Mechanics*, vol. II, Dover Publ. (1965).
36. Tritton, D.J., "Experiments on the Flow Past a Circular Cylinder at Low Reynolds Numbers," *J. Fluid Mechanics*, 6, pt 4, pp 547-560.
37. Berger, E. and Wille, R., "Periodic Flow Phenomena," *Ann. Rev. Fluid Mechanics*, 4, pp 313-340 (1972).
38. Marrow, T.B. and Kline, S.J., "The Evaluation and Use of Hot-wire and Hot Film Anemometers in Liquids," *Stanford Univ. Rep. MD-25* (1971).
39. Kohan, S. and Schwarz, W.H., "Low Speed Calibration Formula for Vortex Shedding from Cylinders," *Physics Fluids*, 16, pp 1528-1529 (1973).
40. Mair, W.A. and Maull, D.J., "Bluff Bodies and Vortex Shedding - a Report on Euromech 17," *J. Fluid Mechanics*, 45, pt 2, pp 209-224 (1971).
41. Tritton, D.J., "A Note on Vortex Streets behind Circular Cylinders at Low Reynolds Numbers," *J. Fluid Mechanics*, 45, pt 1, pp 203-208 (1971).
42. Taneda, S., "Experimental Investigation of the Wakes behind Cylinders and Plates at Low Reynolds Numbers," *J. Phys. Soc. Japan*, 11, p 1284 (1956).
43. Gerrard, J.H., "The Mechanics of the Formation Region of Vortices behind Bluff Bodies," *J. Fluid Mechanics*, 25, pt 2, pp 401-413.
44. Jaminet, J.F. and Van Atta, C.W., "Experiments on Vortex Shedding from Rotating Circular Cylinders," *AIAA J.*, 7 (9), pp 1817-1819.
45. Schiller, L. and Linke, W., "Druck-und Reibungswiderstand des Zylinders bei Reynoldsschen Zahlen 5000 bis 40000," *Z.F.M., Jahrg. 24, Nr. 7*, pp 193-198 (Apr 13, 1933) (in English-NACA TM 715).
46. Bearman, P.W., "On Vortex Shedding from a Circular Cylinder in the Critical Reynolds Number Regime," *J. Fluid Mechanics*, 3, pt 3, pp 577-585.
47. Jones, G.W., Cincotta, J.J., and Walker, R.W., "Aerodynamic Forces on Stationary and Oscillating Circular Cylinders at High Reynolds Numbers," *NASA TR R-300* (Feb 1969).
48. Schmitt, L.V., "Measurements of Fluctuating Air Loads on a Circular Cylinder," *J. Aircraft*, 2 (1), pp 49-55 (Jan/Feb 1965).
49. Schlinker, R.H., Fink, M.R., and Amiet, R.K., "Vortex Noise from Non-Rotating Cylinders and Airfoils," *AIAA Paper* 76-81 (Jan 1976).
50. Roshko, A., "Experiments on the Flow Past a Circular Cylinder at Very High Reynolds Number," *J. Fluid Mechanics*, 10, pp 345-356.
51. Knauss, D.T., John, J.E.A., and Marks, C.H., "The Vortex Frequencies of Bluff Cylinders at Low Reynolds Numbers," *J. Hydronautics*, 10 (4), pp 121-126 (Oct 1976).
52. Huthloff, E., "Windkanaluntersuchungen zur Bestimmung der periodischen Kräfte bei der Umströmung schlanker scharfkantiger Körper," *Stahlbau*, 44 (4), pp 97-103 (Apr 1975).
53. Lee, B.E., "The Effect of Turbulence on the Surface Pressure Field of a Square Prism," *J. Fluid Mechanics*, 69, pt 2, pp 263-282.
54. Twigge-Molecey, C.F.M. and Baines, W.D., "Aerodynamic Forces on a Triangular Cylind-

- der," ASCE J. Engr. Mechanics Div., 99 (EM 4), pp 803-818 (Aug 1973).
55. Roshko, A., "On the Drag and Shedding Frequency of Two-Dimensional Bluff Bodies," NACA TN 3169 (July 1954).
 56. Bearman, P.W., "On Vortex Street Wakes," J. Fluid Mechanics, 28, pt 4, pp 625-641.
 57. Griffin, O.M., "Universal Strouhal Number for the 'Locking-on' of Vortex Shedding to the Vibrations of Bluff Cylinders," J. Fluid Mechanics, 85, pt. 3, pp 591-606 (Apr 1978).
 58. Griffin, O.M., Skop, R.A., and Koopmann, G.H., "The Vortex Excited Resonant Vibrations of Circular Cylinders," J. Sound Vib., 31 (2), pp 235-249 (1973).
 59. Griffin, O.M. and Koopmann, G.H., "The Vortex Excited Lift and Reaction Forces on Resonantly Vibrating Cylinders," J. Sound Vib., 54 (3), pp 435-448 (1977).
 60. Naudascher, E. and Rockwell, D., "Oscillator Model Approach to the Identification and Assessment of Flow-Induced Vibrations in a System," J. Hydraul. Res., 18 (1), pp 59-82 (1980).
 61. Proc. IUTAM-IAHR Symp. Flow-Induced Struct. Vib., Karlsruhe, Germany (1972).
 62. Sallet, D.W., "Symposium on Practical Experiences with Flow-Induced Vibrations," Karlsruhe, Germany (Sept 3-6, 1979), Shock Vib. Dig., 12 (1), pp 36-40 (Jan 1980).
 63. Proc. Flow-Induced Vibrations Symp., 3rd Natl. Congress Pressure Vessel Piping Tech., San Francisco, Cal., June 25-29, 1979, publ. by ASME (1979).
 64. E Naudascher (ed), Flow-Induced Structural Vibrations, Springer-Verlag (1974).
 65. Eaton, K.J., (ed), Proc. the 4th Intl. Conf. Wind Effects Bldgs. Struct., Heathrow (1975), Cambridge Univ. Press.
 66. Griffin, O.M., "Flow near Self-Excited and Forced Vibrating Circular Cylinders," J. Engr. Indus., Trans. ASME, 94, pp 539-547 (May 1972).
 67. Dale, J.R. and Holler, R.A., "Vortex Wakes from Flexible Circular Cylinders at Low Reynolds Numbers," 1-225 974, copy 1, U.S. Naval Air Dev. Center, Johnsville, Warminster, PA.
 68. Umemura, S., Yamaguchi, T., and Shiraki, K., "On the Vibration of Cylinders Caused by Karman Vortex," Bull. JSME, 14 (75), pp 929-937 (1971).
 69. Feng, C.C. and Parkinson, G.V., paper given at Euromech 17 (1970).
 70. Skop, R.A., Ramberg, S.E., and Ferer, K.E., "Added Mass and Damping Forces on Circular Cylinders," NRL Report 7970 (Mar 19, 1976).
 71. Meier-Windhorst, A., "Flatterschwingungen von Zylindern im gleichmässigen Flüssigkeitsstrom," Mitteilungen des Hydraulischen Instituts der Technischen Hochschule München, Heft 9, pp 1-29 (1939).
 72. Glass, R., "A Study of the Self-Excited Vibrations of Spring Supported Cylinders in a Steady Fluid Stream," Doctoral Thesis, Univ. Maryland (1966).
 73. Toebes, G.H. and Eagleston, P.S., "Hydroelastic Vibrations of Flat Plates Related to Trailing Edge Geometry," J. Basic Engr., Trans. ASME, pp 671-678 (Dec 1961).
 74. Bishop, R.E.D. and Hassan, A.Y., "The Lift and Drag Forces on a Circular Cylinder Oscillating in a Flowing Fluid," Proc. Royal Soc. (London), Ser. A, 277, pp 51-75 (1964).
 75. Diana, G. and Falco, M., "On the Forces Transmitted to a Vibrating Cylinder by a Blowing Fluid," Meccanica, 6, pp 9-22 (1971).
 76. Hartlan, R. and Currie, I., "A Lift-Oscillator Model for Vortex Induced Vibrations," ASCE J. Engr. Mechanics Div., 96, pp 571-591 (1970).

77. Skop, R.A. and Griffin, O.M., "A Model for the Vortex-Excited Resonant Vibrations of Bluff Bodies," *J. Sound Vib.*, 27, pp 225-233 (1973).
78. Tanida, Y., Okajima, A., and Watanabe, Y., "Stability of a Circular Cylinder Oscillating in Uniform Flow or in a Wake," *J. Fluid Mechanics*, 61, pt 4, pp 769-784.
79. Kovaznay, L.G.S., "Hot-Wire Investigation of the Wake Behind Cylinders at Low Reynolds Numbers," *Proc. Royal Soc., (London) Ser. A*, 198 (1053), pp 174-190 (1949).
80. Hanson, A.R., "Vortex Shedding from Yawed Cylinders," *AIAA J.*, 4 (4), pp 738-740.
81. Lugt, H.J. and Haussling, H.J., "Laminar Flows Past a Flat Plate at Various Angles of Attack," Lecture Notes (no. 8) in *Physics*, Springer-Verlag (1971).
82. Jordan, S.K. and Fromm, J.E., "Oscillating Drag Lift and Torque on a Circular Cylinder in a Uniform Flow," *Physics Fluids*, 15 (3), pp 371-376 (Mar 1972).
83. McGregor, O.M., "An Experimental Investigation of the Oscillating Pressures on a Circular Cylinder in a Fluid Stream," *UTIA. Tech. Note No. 14* (June 1957).
84. Gerrard, J.H., "An Experimental Investigation of the Oscillating Lift and Drag of a Circular Cylinder Shedding Turbulent Vortices," *J. Sound Vib.*, pp 244-256.
85. Relf, E.F. and Simmons, L.F.G., "The Frequency of the Eddies Generated by the Motion of Circular Cylinders through a Fluid," *Aeronaut. Res. Comm. (London)*, R and M, no. 917 (June 1924).
86. Drescher, H., "Messung der auf Querangeströmte Zylinder Ausgeübten Zeitlich Veränderten Drücke," *Z. Flugwiss.*, 4, Heft 1/2, p 17 (1956).
87. Delany, M.K. and Sorenson, M.E., "Low Speed Drag of Cylinders of Various Shapes," *NACA TN 3038* (1953).
88. Warren, W.F., "An Experimental Investigation of Fluid Forces of an Oscillating Cylinder," Ph.D. Thesis, Univ. Maryland (1962).
89. Kuwahara, K., "Study of Flow Past a Circular Cylinder by an Inviscid Model," *J. Phys. Soc. Japan*, 45 (1), pp 292-297 (July 1978).
90. Takao, Y., *IBM Japan Sci. Ctr., Rep. G318-1909-0* (1973).
91. Fung, Y.C., "Fluctuating Lift and Drag Acting on a Cylinder in a Flow at Supercritical Reynolds Numbers," *J. Aerospace Sci.*, 27 (11), pp 801-814 (Nov 1960).
92. Schmidt, L.V., "Measurements of Fluctuating Air Loads on a Circular Cylinder," *J. Aircraft*, 2 (1), pp 49-55 (Jan/Feb 1965).
93. Schlichting, H., *Boundary Layer Theory* (6th ed), McGraw-Hill, p 17, fig. 1.4.

ANNUAL ARTICLE INDEX

FEATURE ARTICLES

	ISSUE	PAGES
Munjal, M.L. Evaluation and Control of the Exhaust Noise of Reciprocating I.C. Engines	1	5-14
GangaRao, H.V.S. and Haslebacher, C.A. Vibration Analysis of Highway Bridges	2	3-8
Wittlin, G. Aircraft Crash Dynamics: Some Major Considerations	3	3-15
Markus, S. and Nanasi, T. Vibration of Curved Beams	4	3-14
Fawcett, J.N. Chain and Belt Drives - A Review	5	5-12
DiMaggio, F.L. Dynamic Response of Fluid-Filled Shells - An Update	6	3-6
Ramamurti, V. and Srinivasan, V. Machine Tool Vibration - A Review	7	3-8
Griffin, M.J. Biodynamic Response to Whole-Body Vibration	8	3-12
Ignaczak, J. Linear Dynamic Thermoelasticity - A Survey	9	3-8
Jones, N. Recent Progress in the Dynamic Plastic Behavior of Structures, Part III	10	3-16
Attenborough, K. Sound Attenuation Over Ground Cover III	11	3-6
Reddy, J.N. Finite-Element Modeling of Layered, Anisotropic Composite Plates and Shells: A Review of Recent Research	12	3-12

LITERATURE REVIEWS

	ISSUE	PAGES
Huseyin, K. Vibrations and Stability of Mechanical Systems: II	1	21-29
Nakra, B.C. Vibration Control with Viscoelastic Materials - II	1	17-20
Etter, P.C. Underwater Acoustic Modeling Techniques	2	11-20
Massoud, M. Impedance Methods for Machine Analysis	3	17-21
Roberts, J.B. Response of Nonlinear Mechanical Systems to Random Excitation. Part I: Markov Methods	4	17-28
Roberts, J.B. Response of Nonlinear Mechanical Systems to Random Excitation. Part 2: Equivalent Linearization and Other Methods	5	15-29
Chang, C.H. Vibrations of Conical Shells	6	9-17
Waberski, A. Method of R-Functions and Its Application to Analysis of Vibrations of Plates and Other Structures	7	11-14
Leis, B.N. and Broek, D. The Role of Similitude in Fatigue and Fatigue Crack Growth Analyses	8	15-28
Ibrahim, R.A. Parametric Vibration. Part VI: Stochastic Problems (2)	9	23-35
Leissa, A.W. Plate Vibration Research, 1976 - 1980: Classical Theory	9	11-22
Leissa, A.W. Plate Vibration Research, 1976 - 1980: Complicating Effects	10	19-36
Fleischmann, S.T. and Sallet, D.W. Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomenon. Part I	11	9-22
Fleischmann, S.T. and Sallet, D.W. Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomenon. Part II	12	15-24

BOOK REVIEWS

STATISTICAL ENERGY ANALYSIS OF DYNAMIC SYSTEMS

R.H. Lyons
MIT Press, Cambridge, MA

Large and lightweight aircraft and other structures, including houses have focused interest on higher modal analysis for predicting structural fatigue, equipment failure, and noise production. Traditional analyses of mechanical system vibration of machines and structures were concerned with lower resonant modes. Statistical energy analysis (SEA), which is expressed in terms of random parameters, is now being utilized by mechanical and structural engineers.

The prime advantage of SEA is that a large number of modes can be compressed into a few coherent features of the modal pattern (direct field and a few early reflections), and the incoherent pattern (reverberant field) can be compressed into a few frequency bands. In addition, SEA allows for a simple description of a system; modes or waves are used to describe the field.

The 15 chapters of the book are contained in two parts; the numerous references are annotated.

Part I on basic theory consists of four chapters. The history and development of SEA, and single- and multi-degree-of-freedom systems are described. The storage of kinetic and potential energy by modes in free and forced vibration plus the decay or rate of energy removed by damping are considered.

Chapter III introduces the concept of average power flow - average in both ensemble and temporal sense between simple single- and more complicated multi-degree of freedom-systems. The idea of blocked systems, similar to that used in electrical systems, is introduced. Power flow in terms of both blocked and coupled system energies are considered; the idea of enlarged modal interactions as a white noise source is presented.

Chapter IV considers the problems of estimating response using average energy distribution. The estimation of displacement and stresses leads to the development of intervals of estimating and confidence coefficients. This is important when statistical analysis of variance shows that the standard deviation is an appreciable fraction of the mean.

Part II centers upon engineering applications of SEA in predicting vibration. Four chapters discuss response estimation during the early stages in the design of a high-speed flight vehicle; dynamic response of a system in terms of stress, acceleration, and pressure; estimations of the average system energy from the SEA model and knowledge of its parameters. The use of such SEA parameters as loss factor, power transfer parameters, and modal density of a system plus the important input power prediction are described. The ratio of the convection speed of pressure waves to the bending wave speed in a turbulent boundary layer is given.

The next three chapters show how the system can be modeled and define subsystems; included are the identification and evaluation of coupling between systems. Parameter evaluation, which is the engineering basis for SEA, is illustrated by measuring damping in both simple and built-up structures, including constraint layer structures.

The author illustrates the evaluation of coupling loss factors by applying them to aerospace structures, acoustical spaces, cylinders, and coupling between structural subsystems. An example is given of the use of SEA in the response estimation of a re-entry vehicle; information on modal density, high-frequency modal coupling loss factors, and the experimental procedures required to determine the parameters are described.

The reviewer has noticed that the most important uses to date have been in noise control problems, noise propagation in ships, and vibrations in nuclear reactors and enclosed space structures. SEA has a major stumbling block: the determination of param-

eters from experimental tests. The reviewer does recommend this book to engineers involved in this subject. However, more work must be done.

H. Saunders
General Electric Co.
Schenectady, NY

DYNAMICS OF MECHANICAL SYSTEMS

J.M. Prentis
Halsted Press, New York, NY
1980, 486 pages, 2nd Edition

This undergraduate text contains material that would typically be found in separate books on machine dynamics, vibrations, and automatic control theory. The entire text would be suitable for a two-semester senior level course; a one semester course could be based on selected chapters. The chapter by chapter contents are as follows:

Chapter 1 - Simple Mechanisms I. This short introductory chapter to the first one-third of the book is devoted to the classification of plane and spatial mechanisms.

Chapter 2 - Simple Mechanisms II. The practical kinematics of planar mechanisms such as cams, gears, gear trains, and linkages are illustrated. The mathematical presentation is based on elementary calculus, without reference to vectors or complex numbers.

Chapter 3 - Force Relationships in Mechanisms I Transmitted Forces and Friction. The first part of this brief chapter considers frictionless mechanisms. The virtual work concept applied to friction is introduced. The chapter concludes with a study of the effects of friction on cams, four-bar, and slider-crank mechanisms.

Chapter 4 - Velocities and Accelerations. The vector kinematic relations for moving spatial reference frames are derived at the beginning of the chapter. The relations are then applied mainly to such planar mechanisms as cams and linkages; the concept of equivalent mechanisms is introduced.

Chapter 5 - Force Relations in Mechanisms II Inertia Forces. This 60-page chapter covers D'Alembert's principle, balancing concepts, gyroscopic effects, angular momentum, plane motion inertia, transmission of inertia forces, and inertial stresses. Analytical and graphical methods are emphasized.

Chapter 6 - I First Order Systems. The automatic control third of the book is introduced with this chapter on lumped parameter modeling. Proportional elements, integrating elements, transfer relations, response, lag, and superposition are described mathematically and physically using differential equations and complex numbers.

Chapter 7 - II Second Order Systems. Chapter 7 is a continuation of the previous chapter. The concepts of amplitude, phase, and frequency are described mathematically and illustrated using spring-mass systems and servo-mechanisms.

Chapter 8 - Automatic Control. This very long chapter deals with the standard topics of open and closed loop systems, derivative control and integral control, position and speed control, stability criteria, Bode diagrams, and system design. The presentation is mainly theoretical; there are illustrations of the application of the theory to practical systems.

Chapter 9 constitutes almost one third of the book. It follows logically the modeling techniques introduced in the chapter on automatic control. The classical spring-mass system, isolation techniques, seismic excitation, and phase plane analysis are considered. Simple multi-degree-of-freedom systems are analyzed. Energy concepts and the Rayleigh method are applied to lumped and distributed systems. Elementary rotor dynamics are also considered.

A section containing practice problems keyed to the chapters follows the last chapter; the answers are given. An index concludes the book.

There is always the danger that a textbook purporting to cover such a wide range of topics will do none of them, or its readers, justice. For the most part the author has successfully avoided this trap. To my personal taste chapters 5 and 9 which deal with dynamics and chapter 8 on automatic control are a bit lean. I would have preferred a stronger treatment and more applications. Another reviewer might say the same about other sections.

Considering the intended usage, and the latitude given the instructor to introduce additional material, the author has produced a reasonable compromise.

The text is well illustrated with clearly marked line drawings. The typeset and organization are pleasing to the eye. The style and exposition are easy to read. Students will probably be pleased with the quantity of well-written descriptive material, which is generally more voluminous than is found in American technical books.

H.J. Sneek
Department of Mechanical Engineering,
Aeronautical Engineering & Mechanics
Rensselaer Polytechnic Institute
Troy, New York

DYNAMICS IN CIVIL ENGINEERING: ANALYSIS AND DESIGN

A. Major
Akadémiai Könyvkiadó, Budapest, Hungary
Vol. I-IV, 1981, 1212 pages, \$96.00

Vibration problems caused by time-dependent loads arise in many structures. This comprehensive reference book deals with the theoretical and practical aspects of solving such dynamic problems, which are often very complex. This book is a completely revised and considerably enlarged edition of the internationally known author's 1961 work, *Vibration Analysis and Design of Foundations for Machines and Turbines*, which is a standard reference book for many engineers.

The extended scope of this second edition includes more detailed treatment of the fundamentals of structural dynamics and their practical applications. To assure convenient handling of this increased material, the book has been divided into four volumes. The fourth volume is devoted to wind and earthquake effects on tall buildings and various industrial structures and the dynamics of bridges.

The first volume (320 pp) contains a condensed but up-to-date introduction to structural and soil dynamics. In addition, the reader is exposed to the fundamental principles governing the design of machine foundations. The second volume (302 pp) deals with the vibratory characteristics of such machines as hammers and reciprocating engines and with the design of their foundations, including vibration isolation and mechanical methods for mitigating undesirable vibration effects.

The third volume (291 pp), a continuation of the subject matter of volume two, deals with high-speed machinery and steam and nuclear power plants. Again, such general considerations as design criteria are followed by descriptions of various computational methods and useful structural details of machine foundations.

The last volume (306 pp) is devoted mostly to vibrations of tall buildings and industrial structures subjected to wind, earthquake, and blast loads. One chapter deals with the dynamics of hydraulic structures. Finally, the reader is introduced to various types of bridge vibration.

The reviewer believes that the four volumes contain a most comprehensive treatment of dynamic problems in civil engineering from a wide variety of fields. Clear presentation of basic theories is followed by practical applications. In addition, a vast amount of pertinent information is given in tables and graphs; such information is not otherwise easily available to the practicing engineer. Application of the various computational methods are illustrated by numerical examples, and the work of the designer is facilitated by numerous figures showing structural details. The author also provides an extensive bibliography, citing 1377 references. The book is well produced, edited, and indexed. The reviewer believes that these volumes represent a significant contribution to the literature of structural dynamics and will become a standard reference book for anyone interested in the dynamic analysis and design of structures.

R. Szilard
University of Dortmund
August-Schmidt-Strasse
4600 Dortmund 50 (Eichlinghofen)

BOOK REVIEWS: 1981

Ariman, T., Liu, S.C., and Nickell, R.E., eds., Lifeline Earthquake Engineering - Buried Pipelines, Seismic Risk and Instrumentation, ASME Special Publ. PVP-34, New York, NY, 1979; Reviewed by L.R.L. Wang, SVD, 13 (3), p 23 (Mar 1981)

Barr, D.F. and Miller, R.K., Basic Industrial Hearing Conservation, Fairmont Press, Atlanta, GA, 1979; Reviewed by R.J. Peppin, SVD, 13 (9), pp 37-38 (Sept 1981)

Bendat, J.S. and Piersol, A.G., Engineering Applications of Correlation and Spectral Analysis, John Wiley and Sons, New York, NY, 1980; Reviewed by H. Saunders, SVD, 13 (11), pp 25-26 (Nov 1981)

Bennett, S.E., Ross, A.L., and Zemanick, P.Z., eds., Failure Prevention and Reliability, ASME, New York, NY, 1977; Reviewed by H. Saunders, SVD, 13 (1), p 30 (Jan 1981)

Blekhman, I.I., ed., Nonlinear Vibration of Mechanical Systems, Volume 2 of Vibratsii v Tekhnike (Engineering Vibration), Chelomei, V.N., ed., Mashinostroenie, Moscow, 1979 (in Russian); Reviewed by M. Dublin, SVD, 13 (3), p 25 (Mar 1981)

Bolotin, V.V., ed., Vibration of Linear Systems, Volume 1 of Vibratsii v Tekhnike (Engineering Vibration), Chelomei, V.N., ed., Mashinostroenie, Moscow, 1978 (in Russian); Reviewed by M. Dublin, SVD, 13 (3), pp 24-25 (Mar 1981)

Bolotin, V.V., Sluchainye Kolebaniya Uprugikh Sistem (Random Vibration of Elastic Systems), Nauka, Glavnaya Redaktsiya Fiziko-matematicheskoi Literatury, Moscow, 1978 (in Russian); Reviewed by M. Dublin, SVD, 13 (7), p 15 (July 1981)

Buzdugan, G., Mihailescu, E., and Rades, M., Vibration Measurement, Rumanian Socialist Republic Academic Press, 1979 (in Rumanian); Reviewed by P. Ibanez, SVD, 13 (1), pp 31-32 (Jan 1981)

Carneiro, F.L.L.B., Ferrante, A.J., and Brebbia, C.A., eds., Offshore Structures Engineering, Gulf Publishing Co., Houston, TX, 1979; Reviewed by K.E. McKee, SVD, 13 (4), p 29 (Apr 1981)

Chen, S.S. and Bernstein, M.D., eds., Flow Induced Vibrations, ASME, New York, NY, 1979; Reviewed by D.W. Sallet, SVD, 13 (6), pp 19-21 (June 1981)

Clarkson, B.L., ed., Stochastic Problems in Dynamics, Fearon-Pitman Publ., Belmont, California; Reviewed by H. Saunders, SVD, 13 (4), pp 29-30 (Apr 1981)

Close, C.M. and Frederick, D.K., Modeling and Analysis of Dynamic Systems, Houghton Mifflin Co., Boston, MA, 1978; Reviewed by J.M. Prentis, SVD, 13 (9), pp 36-37 (Sept 1981)

Decker, K.-H., Maschinenelemente, Gestaltung und Berechnung, 7th Edition, Carl Hauser Vg., München, Fed. Rep. Germany, 1975 (in German); Reviewed by G. Schweitzer, SVD, 13 (2), pp 21-22 (Feb 1981)

Edelen, D.G.B., Lagrangian Mechanics of Nonconservative Nonholonomic Systems, Noordhoff International Publishing, Leyden, The Netherlands, 1977; Reviewed by H.K. Sachs, SVD, 13 (1), p 31 (Jan 1981)

Irons, B. and Ahmad, S., Techniques of Finite Elements, John Wiley and Sons, Somerset, NJ, 1980; Reviewed by A.J. Kalinowski, SVD, 13 (10), pp 37-38 (Oct 1981)

Kawata, K. and Jumpei, S., eds., High Velocity Deformation of Solids, Springer-Verlag, Berlin, 1978; Reviewed by S.E. Benzley, SVD, 13 (2), p 21 (Feb 1981)

Kuttruff, H., Room Acoustics, Applied Science Publishers, Ltd., London, UK, 2nd Edition, 1979; Reviewed by D.M. Yeager, SVD, 13 (11), pp 23-24 (Nov 1981)

Lalanne, M., Berthier, P., and Der Hagopian, J., Mécanique Des Vibrations Linéaires, Masson Publ., Paris, France, 1980 (in French); Reviewed by F.C. Nelson, SVD, 13 (8), pp 30-31 (Aug 1981)

Lyons, R.H., Statistical Energy Analysis of Dynamic Systems, MIT Press, Cambridge, MA; Reviewed by H. Saunders, SVD, 13 (12), pp 27-28 (Dec 1981)

Mader, C.L., Numerical Modeling of Detonations, University of California Press, Berkeley, CA, 1979; Reviewed by J.J. Dick, SVD, 13 (6), pp 18-19 (June 1981)

Magrab, E.B., Vibrations of Elastic Structural Members, Sijthoff & Noordhoff, Alphen aan den Rijn, The Netherlands, 1979; Reviewed by K.E. McKee, SVD, 13 (4), pp 30-31 (Apr 1981)

Main, I.G., Vibrations and Waves in Physics, Cambridge University Press, New Rochelle, NY, 1978; Reviewed by A.J. Kalinowski, SVD, 13 (11), pp 24-25 (Nov 1981)

Major, A., Dynamics in Civil Engineering: Analysis and Design, Akadémiai Könyvkiadó, Budapest, Hungary, Vol. I-IV, 1981; Reviewed by R. Szilard, SVD, 13 (12), p 29 (Dec 1981)

Nayfeh, A.H. and Mook, D.T., Nonlinear Oscillations, John Wiley and Sons, New York, NY, 1979; Reviewed by R.A. Ibrahim, SVD, 13 (5), pp 31-32 (May 1981)

Oden, J.T. and Reddy, J.N., Variational Methods in Theoretical Mechanics, Springer-Verlag, Vienna and New York, 1976; Reviewed by H. Saunders, SVD, 13 (10), p 39 (Oct 1981)

Otnes, R.K. and Enochson, L., Applied Time Series Analysis - Volume 1. Basic Techniques, John Wiley and Sons, New York, NY, 1978; Reviewed by H. Saunders, SVD, 13 (9), pp 38-40 (Sept 1981)

Paul, B., Kinematics and Dynamics of Planar Machinery, Prentice Hall, Inc., Englewood Cliffs, NJ, 1979; Reviewed by H. Saunders, SVD, 13 (8), pp 29-30 (Aug 1981)

Paz, M., Structural Dynamics Theory and Computation, Van Nostrand Reinhold Co., New York, NY, 1980; Reviewed by K.E. McKee, SVD, 13 (5), p 30 (May 1981)

Perrone, N. and Pilkey, W., eds., Structural Mechanics Software Series, Volume III, University Press of Virginia, Charlottesville, VA, 1980, Reviewed by M.M. Hurwitz, SVD, 13 (6), p 19 (June 1981)

Phillips, O.M., The Dynamics of the Upper Ocean, Cambridge University Press, New Rochelle, NY, 2nd Edition, 1977; Reviewed by J.R. Breton, SVD, 13 (10), p 37 (Oct 1981)

Pipes, R.B., ed., Nondestructive Evaluation and Flaw Criticality for Composite Materials, American Society for Testing and Materials (STP 696), Philadelphia, PA, 1979; Reviewed by S.E. Benzley, SVD, 13 (8), p 30 (Aug 1981)

Prentis, J.M., Dynamics of Mechanical Systems, Halsted Press, New York, NY, 2nd Edition, 1980; Reviewed by H.J. Sneck, SVD, 13 (12), pp 28-29 (Dec 1981)

Rades, M., Identification of Vibrating Systems, Rumanian Socialist Republic Academic Press, 1979 (in Rumanian); Reviewed by P. Ibáñez, SVD, 13 (2), pp 22-23 (Feb 1981)

Rosenberg, R.M., Analytical Dynamics of Discrete Systems, Plenum Press, New York, NY, 1977; Reviewed by R.A. Scott, SVD, 13 (3), pp 22-23 (Mar 1981)

Simiu, E. and Scanlan, R.H., Wind Effects on Structures, John Wiley and Sons, New York, NY, 1980; Reviewed by K.E. McKee, SVD, 13 (5), pp 30-31 (May 1981)

Taplin, D.M.R., Advances in Research on the Strength of Metals, Volume 2B - Fatigue, Pergamon Press, New York, NY, 1978; Reviewed by H. Saunders, SVD, 13 (7), pp 15-16 (July 1981)

Tominari, N., Seto, K., and Okada, J., Analysis and Design of Servo Control Systems, Corona Publishing Co., Ltd., Tokyo, Japan, 1979 (in Japanese); Reviewed by T. Iwatsubo, SVD, 13 (7), pp 16-17 (July 1981)

SHORT COURSES

JANUARY

PROBABILISTIC AND STATISTICAL METHODS IN MECHANICAL AND STRUCTURAL DESIGN

Dates: January 11-15, 1982

Place: Tucson, Arizona

Objective: The objective of this short course and workshop is to review the elements of probability and statistics and the recent theoretical and practical developments in the application of probability theory and statistics to engineering design. Special emphasis will be given to fatigue and fracture reliability.

Contact: Special Professional Education, Harvill Building No. 76, Room 237, College of Engineering, The University of Arizona, Tucson, AZ 85721 - (602) 626-3054.

MACHINERY VIBRATION ANALYSIS

Dates: January 26-29, 1982

Place: Tampa, Florida

Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow speed paper rolls.

Contact: Dr. Ronald L. Eshleman, The Vibration Institute, 101 West 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

FEBRUARY

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: February 1-5, 1982

Place: Santa Barbara, California

Dates: March 1-5, 1982

Place: College Park, Maryland

Dates: April 12-16, 1982

Place: Dayton, Ohio

Dates: July 19-23, 1982

Place: England

Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

VIBRATION TESTING AND SIGNAL ANALYSIS

Dates: February 16-18, 1982

Place: Southampton, England

Objective: Topics include: types of testing; introduction to the various types of signal-linear system theory, etc. (i) testing with applied excitation - techniques - steady state, slow sweep, transient, random, (ii) response analysis (only) - system in motion due to natural excitation; instrumentation and signal conditioning - effects of attachments on system characteristics; instrumentation system characteristics; limitations, e.g. bandwidth, integration, analogue filtering, etc; signal processing; and specification testing.

Contact: Mrs. G. Hyde, ISVR Conference Secretary, The University, Southampton, SO9 5NH - (0703) 559122, Ext. 2310.

BALANCING OF ROTATING MACHINERY

Dates: February 23-26, 1982

Place: Galveston, Texas

Objective: The seminar will emphasize the practical aspects of balancing in the shop and in the field. The instrumentation, techniques, and equipment pertinent to balancing will be elaborated with case histories. Demonstrations of techniques with appropriate instrumentation and equipment are scheduled. Specific topics include: basic balancing techniques (one- and two-plane), field balancing, balancing without phase measurement, balancing machines, use of programmable calculators, balancing sensitivity, flexible rotor balancing, and effect of residual shaft bow on unbalance.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MARCH

MEASUREMENT SYSTEMS ENGINEERING

Dates: March 1-5, 1982

Place: Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS

Dates: March 8-12, 1982

Place: Phoenix, Arizona

Objective: Program emphasis is on how to increase productivity, cost-effectiveness of data acquisition systems and groups in the field and in the laboratory. Emphasis is also on electrical measurements of mechanical and thermal quantities.

Contact: Peter K. Stein, 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

SHOCK AND VIBRATION CONTROL

Dates: March 16-18, 1982

Place: Southampton, England

Objective: Topics include: introduction - structural parameters and their role in vibration control; dynam-

ic properties of structural materials - damping materials and their properties, application of damping treatments to structures, fibre reinforced plastics, fatigue; mobility methods - concepts, system coupling, application to the isolation problem, approximate methods; vibration transmission through structures - path identification - classical, cross correlation, etc., power flow - mechanisms, use of statistical energy methods, acoustic radiation, radiation efficiency; shock - impacts in machines - effects of structural parameters on acoustic radiation, isolation - machinery installations, the transient environment - packaging and packaging materials.

Contact: Mrs. G. Hyde, ISVR Conference Secretary, The University, Southampton, SO9 5NH - (0703) 559122, Ext. 2310.

APRIL

DESIGN OF FIXED OFFSHORE PLATFORMS

Dates: April 5-16, 1982

Place: Austin, Texas

Objective: This course is dedicated to the professional development of those engineers, scientists, and technologists who are and will be designing fixed offshore platforms to function in the ocean environment from the present into the twenty-first century. The overall objective is to provide participants with an understanding of the design and construction of fixed platforms, specifically the theory and processes of such design and the use of current, applicable engineering methods.

Contact: Continuing Engineering Studies, College of Engineering, Ernest Cockrell Hall 2.102, The University of Texas at Austin, Austin, TX 78712 - (512) 471-3506.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

COMPILATION OF DAMPING DESIGN GUIDE

The Flight Dynamics Laboratory, one of the Air Force Wright Aeronautical Laboratories located at Wright-Patterson Air Force Base Ohio, awarded a three-year contract in September 1981 to Lockheed-California Company, Burbank, California and University of Dayton Research Institute, Dayton, Ohio, to develop an aerospace structures technology damping design guide. The objective of this effort is to collect and summarize available design methods and data on acoustic and vibration control using damping materials/methodology and compile this information into a damping design guide which may be readily applied for use in controlling structure and equipment vibration problems on board aircraft, spacecraft, and other aerospace systems. The design guide will be written for aerospace systems designers and provide to the designer the methods of damping design, limits of application, sources of derivation, and examples illustrating the use of each method.

The scientific/engineering community is invited to offer examples of successful application of damping methods/technology and detailed background information for these examples for inclusion in the damping design guide. Data on available damping material adhesives and compounds are also of interest and will be included in the guide, as will a list of vendors active in this field.

Anyone interested in participating or offering information is urged to contact: J. Soovere, Lockheed-California Company, Dept 63G, Plant A-1, Burbank, California 91520 - (213) 847-2225; M. Drake, University of Dayton Research Institute, Dayton, Ohio 45469 - (513) 229-2644; or V. Miller, Flight Dynamics Laboratory, AFWAL/FIBED, Wright-Patterson Air Force Base Ohio 45433 - (513) 255-5229/5753.

ERRATA

The following errors were noted in the article *Linear Dynamic Thermoelasticity - A Survey*, published in the September issue of the Digest.

"The head conduction equation," page 4, should read "The heat conduction equation."

"The functions ρ, λ, \dots ," page 4, should read "The parameters ρ, λ, \dots ."

"The function θ_0 in equation (3) . . .", page 5, should read "The parameter θ_0 in equation (3) . . ."

INFORMATION RESOURCES

THE METAL MATRIX COMPOSITES INFORMATION ANALYSIS CENTER

MISSION

The MMCIAC, established in October 1980, is one of the newest of the DoD information analysis centers (IACs) administered and funded by the Defense Logistics Agency (DLA) and the Defense Technical Information Center (DTIC). As with the other IACs, the MMCIAC receives its technical sponsorship and guidance from a DoD laboratory, in this case the U.S. Naval Surface Weapons Center at Silver Spring, Maryland. Kaman Temp (a division of Kaman Sciences Corporation) located in Santa Barbara, California, operates and manages the MMCIAC.

The broad mission of the MMCIAC is to provide scientific and technical information analysis service to the DoD, other government agencies, government contractors, and the private sector in the area of metal matrix composite materials.

MMC TECHNOLOGY PROGRAM

Throughout the past decade the DoD has manifested a strong interest in developing Metal Matrix Composite (MMC) materials and has invested an estimated 70 million dollars in this technology over the past ten years. In the late 1970s a MMC "thrust" was implemented to further accelerate the developmental pace. The results of recent efforts directed by the Army, Navy, Air Force, and Defense Advanced Research Projects Agency (DARPA) has advanced the MMC community rapidly toward systems applications. Present efforts focus on making this new technology more cost effective.

The MMC technology program, over the past 12 years, however, has resulted in a growing, but fragmented data base. Current programs are producing a large amount of technical data and information that, within a short time, will equal and possibly surpass all the data previously generated. Therefore,

a need exists to centrally accumulate, evaluate, analyze, and disseminate this technical data and information through a well developed and dedicated technology transfer program. The DoD Metal Matrix Composites Information Analysis Center was established as the basic element of such a program.

TECHNICAL SCOPE

The subject matter coverage of the MMCIAC is the technology related to metal matrix composite materials. The materials are understood to be those composites that perform acceptably under severe conditions, both environmental and operational. The materials are those characterized as having high specific properties, proven environmental fatigue capability, reduced requirement for critical metals, improved creep and wear resistance, high design flexibility, high damage tolerance, and unique combinations of properties including mechanical, electrical, and thermal. The scope of this coverage embraces:

- Continuous fibers, wires, discontinuous whiskers with L/D 10, directionally solidified eutectics
- Fibers -- boron, graphite, silicon carbide, borsic, nitride, alumina, boron carbide, titanium diboride
- Wires -- stainless steel, tungsten, molybdenum, beryllium, titanium, niobium alloys and compounds
- Whiskers -- alumina, silicon carbide, silicon nitride
- MMC Systems -- alumina/magnesium, beryllium/titanium, boron/stainless steel/aluminum, boron/titanium/aluminum, borsic/aluminum, borsic/titanium, copper/graphite, graphite/lead, graphite/aluminum, tungsten/nickel.

Technical areas of interest for the MMCIAC include: manufacturing, fabrication process development,

defense systems applications, performance computations, cost, test and evaluation techniques and methods, properties data, operational serviceability and repair, environmental protection, sources, suppliers, and other MMC-related areas.

MMC PROPERTIES DATA BASE

A special function of the Center is to establish and maintain an MMC properties data base from which to develop information useful to designers concerned with MMC applications. Documents acquired by the Center may contain or reference MMC test data that substantiate derived conclusions and/or analytical results. In these instances, supporting test data are examined and screened for potential MMCIAC data base incorporation. Properties and test data selected for incorporation are evaluated, formatted and placed into an MMC data base organized for selective retrieval and analysis. The data summaries or data books produced from the MMC data base will be disseminated periodically to the Center's users.

INFORMATION OPERATIONS

The MMCIAC provides the facilities and capabilities to: (1) identify, collect, process, store, and disseminate authoritative MMC information; (2) prepare or sponsor the preparation of the necessary products and services to communicate this information to researchers, practicing specialists, manufacturers, and other users with interests and concerns in metal matrix composites; and (3) coordinate and augment existing information activities to improve the transmittal of this information to interested organizations and individuals in the government, military, and private sector.

Center activities include the collection, review, evaluation, analysis, dissemination of the literature related to MMC materials, and assisting visitors in using data files. Emphasis is placed on screening, filtering, and selective reduction to maintain a data base that truly reflects the current state-of-knowledge. MMCIAC personnel continuously review, analyze, refine, and pool worldwide published and unpublished scientific and technical information acquired from the DoD and NTIS and recognized professionals in Government and contractor organizations. They also moni-

tor publications of other IACs and data centers and actively participate in MMC technical conferences and symposia such as the MMC Technology Conference.

The Center's information sources include: Technical reports from DoD, other Government agencies, industry, and academic institutions, etc; open literature including foreign sources; unpublished papers; meetings; technical journals; conferences; workshops; and consultations with key scientists in the MMC community.

PRODUCTS AND SERVICES

The MMCIAC provides a central, authoritative, and easily accessible body of information consistent with MMC materials development and applications. Specifically, it is designed to provide:

- Continuous and comprehensive information acquisition and compilation
- On call, specialized user services for answering technical and bibliographic inquiries from qualified individuals and organizations
- State-of-the-art studies of MMC technology with usefulness extending from the bench level to all levels of RDT&E management
- Scientific and engineering reference works such as handbooks, design manuals and periodic MMC materials properties data summaries
- Critical reviews and assessments of MMC technology and related subjects of significant interest to the Defense RDT&E community
- Current awareness and other user-oriented publications in a quarterly newsletter, notices and proceedings of MMC and related conferences, and announcements with bibliographical accounts of newly acquired information. The quarterly newsletter is available without charge to any interested individual or company engaged in materials research, development, testing, fabrication, and/or applications.

ORGANIZATION AND STAFF

Technical Monitor

U.S. Naval Surface Weapons Center
ATTN: Code R32/Dr. Steven G. Fishman
White Oak Laboratory

Silver Spring, Maryland 20910
(202) 394-2724

Operator

Kaman Tempo (Formerly General Electric-Tempo)
816 State Street
P.O. Drawer QQ
Santa Barbara, California 93102
(805) 963-6497

Manager

Louis A. Gonzalez
Manager - Center Operations
(805) 963-6497

Service Points of Contact

Jacques E. Schoutens
Manager - Data Analysis
(805) 963-6462

William E. Rogers
Manager - Information Services
(805) 963-6482

ABSTRACT CATEGORIES

MECHANICAL SYSTEMS

- Rotating Machines
- Reciprocating Machines
- Power Transmission Systems
- Metal Working and Forming
- Isolation and Absorption
- Electromechanical Systems
- Optical Systems
- Materials Handling Equipment

- Blades
- Bearings
- Belts
- Gears
- Clutches
- Couplings
- Fasteners
- Linkages
- Valves
- Seals
- Cams

- Vibration Excitation
- Thermal Excitation

MECHANICAL PROPERTIES

- Damping
- Fatigue
- Elasticity and Plasticity

STRUCTURAL SYSTEMS

- Bridges
- Buildings
- Towers
- Foundations
- Underground Structures
- Harbors and Dams
- Roads and Tracks
- Construction Equipment
- Pressure Vessels
- Power Plants
- Off-shore Structures

STRUCTURAL COMPONENTS

- Strings and Ropes
- Cables
- Bars and Rods
- Beams
- Cylinders
- Columns
- Frames and Arches
- Membranes, Films, and Webs
- Panels
- Plates
- Shells
- Rings
- Pipes and Tubes
- Ducts
- Building Components

EXPERIMENTATION

- Measurement and Analysis
- Dynamic Tests
- Scaling and Modeling
- Diagnostics
- Balancing
- Monitoring

VEHICLE SYSTEMS

- Ground Vehicles
- Ships
- Aircraft
- Missiles and Spacecraft

ANALYSIS AND DESIGN

- Analog and Analog Computation
- Analytical Methods
- Modeling Techniques
- Nonlinear Analysis
- Numerical Methods
- Statistical Methods
- Parameter Identification
- Mobility/Impedance Methods
- Optimization Techniques
- Design Techniques
- Computer Programs

BIOLOGICAL SYSTEMS

- Human
- Animal

ELECTRIC COMPONENTS

- Controls (Switches, Circuit Breakers)
- Motors
- Generators
- Transformers
- Relays
- Electronic Components

GENERAL TOPICS

- Conference Proceedings
- Tutorials and Reviews
- Criteria, Standards, and Specifications
- Bibliographies
- Useful Applications

MECHANICAL COMPONENTS

- Absorbers and Isolators
- Springs
- Tires and Wheels

DYNAMIC ENVIRONMENT

- Acoustic Excitation
- Shock Excitation

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

MECHANICAL SYSTEMS 41	Gears 61	MECHANICAL PROPERTIES . . 72
Rotating Machines 41	Couplings 61	Damping 72
Reciprocating Machines . . . 48	Fasteners 61	Fatigue 73
Metal Working and	Linkages 62	
Forming 48	Valves 62	
	Seals 62	
		EXPERIMENTATION 75
STRUCTURAL SYSTEMS 48	STRUCTURAL COMPONENTS. 63	Measurement and
Buildings 48	Bars and Rods 63	Analysis 75
Towers 49	Beams 64	Dynamic Tests 76
Foundations 49	Cylinders 64	Diagnostics 77
Underground Structures . . 49	Frames and Arches 64	Balancing 79
Harbors and Dams 50	Panels 65	Monitoring 81
Construction Equipment . . 50	Plates 65	
Power Plants 51	Shells 66	ANALYSIS AND DESIGN . . . 81
Off-shore Structures 52	Pipes and Tubes 68	Analytical Methods 81
	Ducts 69	Modeling Techniques 82
	Building Components 70	Numerical Methods 82
VEHICLE SYSTEMS 52		Statistical Methods 82
Ground Vehicles 52	ELECTRIC COMPONENTS . . . 70	Parameter Identification . . 83
Ships 53	Generators 70	Design Techniques 83
Aircraft 53		Computer Programs 83
Missiles and Spacecraft . . . 54		
MECHANICAL COMPONENTS. 55	DYNAMIC ENVIRONMENT. . . 70	GENERAL TOPICS 85
Absorbers and Isolators . . . 55	Acoustic Excitation 70	Conference Proceedings . . . 85
Blades 56	Shock Excitation 71	Tutorials and Reviews 85
Bearings 56	Vibration Excitation 72	Criteria, Standards, and
		Specifications 86

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 2585, 2593, 2655, 2660, 2661, 2663, 2665, 2666, 2667, 2668, 2669, 2676, 2688)

81-2505

Recognition of the Causes of Rotor Vibration in Turbomachinery

D.M. Smith

Turbine Generator Div., Associated Electrical Industries, Ltd., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 1-4, 11 refs

Key Words: Rotors, Turbomachinery, Oil film bearings, Journal bearings, Vibration source identification

This paper discusses actions which influence rotor vibration and means of recognizing vibration set up by these actions. Attention is given primarily to rotors carried in oil-film journal bearings, as widely used in land and marine turbine plants. Stator vibration which contributes to rotor vibration is taken into account.

81-2506

Double-Frequency Accelerations in Turbogenerator Rotors Resulting from Anisotropy in the Bearings

W. Kellenberger

Brown Boveri, Birr, Switzerland, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 415-420, 5 figs, 3 tables

Key Words: Rotors, Turbogenerators, Acceleration effects, Bearings, Anisotropy

The motion of a turbogenerator rotor in any plane normal to the rotation axis is known to be elliptical. This results in alternating accelerations of all points of the shaft at double-rotation frequency. This paper is concerned with the calculation of these accelerations and the resulting alternating forces which act (at constant speed) on every rotor component (in addition to the steady centrifugal forces) and must be conveyed, over the component's attachment, to the main body of the rotor. Examples of attached

components are: slot-wedges, balancing masses, ventilator fan blades and end-rings.

81-2507

Further Investigations into Load Dependent Low Frequency Vibration of the High Pressure Rotor on Large Turbo-Generators

S.H. Greathead and M.D. Slocombe

N.E. Region Scientific Services Dept., MIMechE, Otley Rd., Harrogate, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 401-413, 15 figs, 2 tables, 6 refs

Key Words: Rotors, Turbogenerators, Nonsynchronous vibration, Low frequencies

This paper presents results from a gland rig which has been built to measure unbalanced steam forces arising in multi-cell shaft labyrinth glands with different geometries and flow conditions. Further operational evidence from observations and measurements on this type of machine obtained during investigations into this load dependent vibration instability is also presented. The gland rig results indicate that large unbalanced steam forces can be generated from steam flow in shaft glands. The operational evidence supports this and also indicates that such forces make an important contribution to the load dependent h.p. rotor instability problems experienced.

81-2508

On the Influence of Casing Stiffness in Turbomachinery Vibration Analysis

S.S. Stecco and M. Pinzauti

Dept. of Energetics, Univ. of Florence, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 139-144, 8 figs, 3 refs

Key Words: Turbomachinery, Critical speeds, Interaction: rotor-casing

Critical frequencies of turbomachines are often highly affected by the interaction effects between casing and rotor. A method, original under various aspects, is presented in order to predict from theoretical values (or, in some cases, from experimental data) the vibrational behavior of the machine. A practical application is also given showing the numerical results.

81-2509

Modal Dynamic Simulation of Flexible Shafts in Hydrodynamic Bearings

H.F. Black and R.D. Brown

Heriot-Watt Univ., Edinburgh, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 109-113, 6 figs, 13 refs

Key Words: Rotors, Flexible shafts, Modal analysis, Non-linear theories

The major sources of non-linearity in flexible rotors are the forces originating from hydrodynamic bearings. When large excitation forces occur, journal motion may be so great that nonlinearity must be considered. The calculation time for nonlinear simulation depends on the number of modes used and the lubricant film force model. An existing Rayleigh-Ritz linear program was adapted for numerical integration. Bearing oil films forces were obtained as time dependent functions using an approximate method. The results presented demonstrate that nonlinear effects can be significant for peak response levels.

81-2510

The Transient Response of Turbo-Alternator Rotor Systems under Short-Circuiting Conditions

J.S. Rao, D.K. Rao, and K.V. Bhaskara Sarma

Indian Inst. of Technology, New Delhi, India, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 271-275, 4 figs, 1 table, 7 refs

Key Words: Rotors, Torsional vibration, Natural shapes, Transfer matrix method, Computer programs

Sudden short-circuiting conditions at the alternator end generate predominant transient torsional oscillations in a turbo-alternator rotor inducing severe dynamic stresses. To evaluate these stresses, a continuous transfer matrix model was developed to determine torsional frequencies and modes. A discrete dynamic system of specified number of rotors is extracted from continuous system and its modes are evaluated by Jacobian method. Transient response is evaluated by modal expansion method. A computer program was developed and the results for a 6MW turbo-alternator system are presented.

81-2511

An Approximate Formula for the Fundamental Fre-

quency of a Uniform Rotating Beam Clamped off the Axis of Rotation

D.H. Hodges

Aeromechanics Lab., U.S. Army Research and Technology Labs. (AVRADCOM), Ames Res. Ctr., Moffett Field, CA, J. Sound Vib., 77 (1), pp 11-18 (July 8, 1981) 5 tables, 8 refs

Key Words: Rotors, Blades, Beams, Rotating structures, Fundamental frequency

A semi-empirical method involving asymptotic expansions is used to obtain an approximate formula for the fundamental frequency of a uniform rotating beam clamped off the axis of rotation. Results from the formula are shown to be of the order of 0.1% different from the exact results for a wide range of rotor speeds and hub radii up to the order of blade length. Thus, the designer is provided with a rapid, very accurate estimate of the frequency, without having to interpolate results from a chart or run a digital computer program.

81-2512

Finite Element Analysis of Rotating Disks

G.L. Nigh and M.D. Olson

Dept. of Civil Engrg., Univ. of British Columbia, Vancouver, British Columbia, Canada, J. Sound Vib., 77 (1), pp 61-78 (July 8, 1981) 8 figs, 1 table, 16 refs

Key Words: Disks (shapes), Rotating structures, Finite element technique, Critical speeds, Viscous damping

A finite element formulation is presented for the analysis of rotating disks in either a body-fixed or a space-fixed co-ordinate system. The in-plane stress distribution resulting from the in-plane body force due to rotation is determined first by a plane stress finite element analysis. This stress distribution is then used in calculating the out-of-plane geometric stiffness which in turn is added to the linear bending stiffness. In the space-fixed co-ordinate system, inertia and a viscous type damping also contribute to the out-of-plane stiffness, even in the steady state case. The formulation presented here places no restrictions on the disk geometry if the problem is solved in a body-fixed co-ordinate system, although only disks of axisymmetric geometry may be considered in the space-fixed co-ordinate system. A direct method of determining the critical speeds through an eigenvalue analysis in space-fixed co-ordinates is presented. The undamped steady state response to a space-fixed transverse point load is then examined. The effects of a viscous type damping are also presented.

81-2513

Reduction of Twice per Revolution Vibration Levels Due to Weight Effect in Large Turbogenerators

N. Bachschmid and G. Diana

Milan Polytechnic, Italy, *Vibrations in Rotating Machinery*, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 203-208, 11 figs, 2 tables, 10 refs

Key Words: Rotors, Turbogenerators, Vibration control, Stiffness coefficients, Asymmetry

A method is presented for determining the rotating stiffness inequality from the static deflection as well as from the twice per revolution vibration measurements. In this way it is possible to verify if, and how strong, dynamical effects due to rotating speed may change the static stiffness inequality distribution. It is further possible to detect where corrections must be applied in order to reduce the twice per revolution vibration levels. This method was applied to a 600 MW generator and proved to be reliable and a successful tool "twice per revolution balancing."

81-2514

Relative Energy Concepts in Rotating System Dynamics

G.T.S. Done

The City Univ., London, UK, *Vibrations in Rotating Machinery*, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 283-287, 5 figs, 4 refs

Key Words: Rotors, Work and energy balance

The concept of relative work and energy; i.e., work and energy expressed relative to nonfixed axes, is not a commonly used one, but it is nevertheless just as valid as that of relative displacement, velocity and acceleration. The basic mechanics are presented in the paper, and it is shown how problems that have arisen in classifying certain types of rotating systems as conservative or nonconservative are resolved. Both absolute and relative energy balances are formulated for two models that exhibit mechanical instability; namely, an unsymmetric cross-section rotating shaft and the lag-plane ("ground resonance") model of a helicopter rotor.

81-2515

Instabilities of Parametric Rotor Support Systems
J. Krodziewski, K. Marynowski, and Z. Parszewski

Politechnika Łódzka, Łódź, Poland, *Vibrations in Rotating Machinery*, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 289-296, 15 figs, 5 refs

Key Words: Rotors, Supports, Parametric response, Stiffener effects

Analysis of instability regions and forced vibrations of parametric discrete/machine/subsystems, interacting with real/supporting/structures is given and applied to model machines with rotors of unequal principal stiffnesses. Laboratory test results are cited and compared with computed ones, regarding instability regions and types of instability, forced vibrations amplitudes and journal center loci. First four harmonics content was computed and plotted for full experimental speed range.

81-2516

A Physical Explanation of Parametric Instabilities in Unsymmetric Rotors

D.A. Peters and I. Zvolanek

Washington Univ., St. Louis, MO, *Vibrations in Rotating Machinery*, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 77-82, 8 figs, 16 refs

Key Words: Rotors, Whirling, Flutter, Parametric excitation

Past work on instabilities in unsymmetric rotors has shown that instabilities can conceivably occur whenever the sum or difference of two natural frequencies equals an integer multiple of the rotor speed. It is also known that some of these potential instabilities are realized neither analytically nor experimentally. In this paper, rules are developed that predict which potential instabilities will occur in the presence of zero damping.

81-2517

Instability Threshold of an Unbalanced, Rigid Rotor in Short Journal Bearings

J.W. Lund and H.B. Nielsen

Dept. of Machine Elements, The Technical Univ. of Denmark, Denmark, *Vibrations in Rotating Machinery*, Proc. 2nd Intl. Conf., Churchill College, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 91-95, 3 figs, 4 refs

Key Words: Rotors, Rigid rotors, Unbalanced mass response, Parametric excitation

The unbalance response of a rigid rotor in short journal bearings is considered. The whirl orbits are assumed to be elliptical at synchronous frequency and are determined from the method of averaging. The stability of the orbital motion is investigated on the basis of the variational equations which include the effect of parametric excitation. The calculated zones of instability are obtained as functions of the Sommerfeld number and a rotor mass parameter for several values of the mass unbalance. The results are shown in a diagram.

81-2518

Acceleration of Unbalanced Rotor through the Resonance of Supporting Structure

F. Victor and F. Ellyin

Dept. of Civil Engrg., Univ. of Sherbrooke, Sherbrooke, Quebec, Canada, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 419-424 (June 1981) 11 figs, 10 refs

Key Words: Rotors, Unbalanced mass response, Resonance pass through, Transverse shear deformation effects, Rotatory inertia effects, Internal damping, Viscous damping

The dynamic response of a simple beam excited at its mid-span by the action of a turbomachine secured to it, is investigated in detail. The forcing function includes transients at startup or shutdown. Effects of the shear deformation, rotatory inertia, and the internal viscous damping, which may depend on the frequency, are considered individually as well as in combined forms. The results indicate that the maximum amplitude of vibration is highly dependent on the acceleration rate through the critical frequency. There is also an apparent shift in its position as compared to the classical resonance frequency. Influences of shear deformation and rotatory inertia are significant when the supporting structure (or foundation) is relatively massive.

81-2519

Fatigue and Fracture Analysis of Two Turbine Shafts

B.N. Leis, K. Dufrane, R. Rungta, R.D. Buchheit, M. Tuttle, P. Skulte, and S. Collard
Battelle Columbus Lab., Columbus, OH, ASME Paper No. 81-PVP-27

Key Words: Shafts, Fatigue life, Crack propagation

A coupled fractographic and mechanics based analysis of radical cracking problems in two low pressure steam turbine

shafts is presented. Cracks occurred at circumferential notches cut in the shaft near shrunk-on discs. Fractography showed fatigue cracks initiated at these notches from pits developed under the action of cyclic bending in a wet stream/condensate environment. Favorable comparison between predicted growth rates and observed growth rates suggest that for this study, fracture mechanics represents a viable tool for turbine shaft design and failure analysis, at least during the crack growth stage. Results also indicate that once the crack is initiated, failure will occur in a matter of days so that corrosion fatigue crack nucleation and the growth of very small cracks dominates the failure process.

81-2520

A Method of Calculating the Vibrational Behaviour of Coupled Rotating Shafts Containing a Transverse Crack

I.W. Mayes and W.G.R. Davies

Central Electricity Generating Board, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 17-27, 9 figs, 9 refs

Key Words: Shafts, Cracked media

A method of calculating the vibrational response of a coupled rotor system to a transverse crack using standard finite-element computer programs is briefly described. The method employs the technique of successive approximations and utilizes the fact that the fractional change in stiffness of a rotor is small even for large cracks and that for speeds away from critical speeds of the shaft, the crack opening and closing is dominated by self-weight bending. The method has been validated by comparing calculations with the experimental results from a four-bearing, two-shaft spin rig, one of whose shafts has a propagating transverse crack. The application of the method to two suspect turbo-generators is described.

81-2521

On the Occurrence of Unstable Vibrations of a Shaft Having Either Asymmetrical Stiffness or Asymmetrical Rotor, Supported by Asymmetrically Flexible Pedestals

H. Ota and K. Mizutani

Dept. of Mech. Engrg., Faculty of Engrg., Nagoya Univ., Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge,

UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 181-186, 6 figs, 1 table, 8 refs

Key Words: Shafts, Rotors, Variable material properties, Vibration response

In a rotating shaft with unequal stiffness or with an asymmetrical rotor, two kinds of unstable vibrations occur. In this paper, the mechanisms which cause the occurrence of unstable vibrations are clearly explained. Conditions under which unstable vibrations occur are derived and ascertained by use of an analog computer.

81-2522

Vibration of a Rotating Shaft Passing through Two Critical Speeds

S. Yanabe and A. Tamura

Tokyo Inst. of Technology, Tokyo, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 19-35, 6 figs, 2 tables, 11 refs

Key Words: Shafts, Critical speeds, Damping effects

The vibration of a rotating shaft which passes through two critical speeds successively under the condition of the uniform acceleration rate is analyzed theoretically taking account of the damping force. The exact solution and its approximate expressions of the nonstationary vibration are derived and their calculated results with respect to various values of the critical speed ratio n and the acceleration parameter Ω_1 are shown. Both results have a good agreement in a wide speed range including the maximum amplitude.

81-2523

A Technique for Modelling Rotors from Measured Vibration Characteristics

G.B. Thomas and P. Littlewood

Central Electricity Generating Board, Harrogate, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 445-451, 6 figs, 1 table, 9 refs

Key Words: Rotors, Mathematical models, Natural frequencies, Mode shapes, Measurement techniques, Stiffness coefficients

The accuracy of rotordynamic calculations is governed by the quality of the available computer model, which for turbo-alternator plant includes three main elements: rotor, bearings and foundations. Existing rotor models are constructed from manufacturers' sectional data idealized empirically to include the stiffening effect of abrupt changes of diameter. A technique for measuring the natural frequencies and modal shapes of individual rotors is described. The measurements were originally intended for comparison with calculations but a method was later developed for calculating an effective stiffness profile from the measured modal shape which was then used to construct a new improved rotor model. Results of rotordynamic calculations from the existing and improved computer models are presented and compared with measured data. The technique has also been used successfully for locating the axial position of rotor cracks.

81-2524

A Contribution for the Calculations of Intermittent Vibrations of Electrically Driven Rotors

U. Hollburg

Technische Universität, Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 339-346, 7 figs, 8 refs

Key Words: Motors, Rotors, Shafts, Amplitude analysis

During the planning of driving mechanisms, consisting of an electromotor, a coupling for the abutting shafts and a processing machine, it is necessary to assess the maximum ratings of the shafts produced by bending and torsional moments. Knowledge is required of the maximum amplitude during intermittent working conditions. Intermittent phenomena of motion of overcritical rotors appear mainly during the running-up since the bending (torsional critical speed) must be passed through until the nominal values are reached. In order to judge the vibrational behavior at the very beginning, the simultaneous consideration of the mechanical system and the electromagnetic process is indispensable. For the description of the various models, a symbolic rotor system is chosen from the many possible driving mechanisms. The continuous bending and torsional elastic shafts with circular cross sections are mounted orthotropically. These shafts are connected by a coupling which is assumed to be elastic. Mathematically, the problem is described by partial differential equations but the complete analytical solution is not obtainable. Thus the problem will be approximately solved by, first of all, determining the Eigenmode of the appointed conservative structure for a discretized finite element model. By means of a connected model transformation a set of ordinary nonlinear differential equations is obtained for which a numerical solution is possible.

81-2525

Torsional Vibrations During the Starting Process in Driving Systems with Three Phase Motors

H. Peeken, C. Troeder, and G. Diekhans

Inst. of Machine Elements and Machine Design, Technical Univ. Aachen, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 427-435, 16 figs, 2 tables, 3 refs

Key Words: Motors, Torsional vibration, Shafts, Drive shafts, Rotating machinery

Induction and synchronous machines produce an oscillation torque on starting which causes strong torsional excitation in connected machinery. A method to measure the air gap torques of the machines in driving systems is presented. With the help of a mathematical model of the machines, it is possible to calculate by digital simulation the torsional response in shaft systems considering that electrical and mechanical system are coupled. Parameter variations in the mechanical system show the dominant effects influencing the air gap torque produced during starting.

81-2526

Investigation of a D.C. Motor Vibration Problem

D. France and H. Grainger

Dynamics Section, Weir Pumps Ltd., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 83-90, 9 figs, 2 refs

Key Words: Motors, Vibration source identification, Resonant frequencies, Mountings, Elastomers

A severe vibration problem was experienced with a D.C. motor used to provide the drive for a paper making machine. The vibration frequency was found to be at the rotor slot number multiplied by rotational speed and distinct resonant regions were evident within the motor operating speed range. The paper describes the various steps taken to identify the excitation source and determine the characteristics of the resonant modes of vibration. Various solutions to the problem were considered and are described. The final solution was achieved by use of an elastomeric mounting arrangement for the motor bearings.

81-2527

Computation of Vibrations of the Coupled System Machine-Foundation

E. Krämer

Technische Hochschule Darmstadt, German Federal Republic, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 333-338, 10 figs, 2 tables

Key Words: Interaction: rotor-foundation, Journal bearings, Rotors, Foundations, Stiffener effects, Vibration response

A procedure is given for computing the unbalance vibrations of rotor-foundation systems. First the foundation is calculated separately. Its influence on the rotor system is represented by its dynamic stiffness at the connecting points to the rotor. With this the expense for computation is reduced to an acceptable level. According to some studies, in many cases it may be possible to assume the foundation as a rigid supporting base.

81-2528

Vibration Analysis of Large Rotor-Bearing-Foundation-Systems Using a Model Condensation for the Reduction of Unknowns

M. Jäcker

Technical Univ., Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 195-202, 10 figs, 4 refs

Key Words: Rotors, Interaction: rotor-foundation

For the dynamic analysis of many rotating structures it is necessary to take into account the dynamic behavior of their foundations. The high analysis costs due to the known complexity of the system can considerably be reduced by a reduction of the unknowns which is based on the speed-independent modal properties of the system components (modal condensation, component mode method). The technique is applied to different linear dynamic problems (stationary and transient response, critical speeds, stability) in a consistent manner. Numerical examples are given for the stationary response problem.

81-2529

Defining the Machine/Foundation Interface

P.E. Simmons

Petrochemical Div., ICI Ltd., Wilton, Middlesbrough, Cleveland, OH, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge,

UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 5-8, 5 figs, 1 ref

Key Words: Interaction: rotor-foundation, Rotors, Foundations

As turbo-machines get larger their dynamic behavior is increasingly affected by the flexibility of their bearings, support structures and foundations. Also larger machines tend to require taller and generally more flexible foundations which are inadequately represented in the machine designer's mathematical model. There is a need for a system which adequately defines the interface and quantifies those characteristics of the foundations which are important to the machine designer. The purpose of this paper is to suggest a standard system of defining the interface which would enable the civil engineer to present the dynamic characteristics of the foundation in a form which the machine designer can use in an improved mathematical model to determine the dynamic behavior of the machine.

81-2530

Stresses of Turbo-Generator Shafts and Foundations Caused by Electrical System Faults

Th. Jainski

Technical Univ., Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 9-16, 10 figs, 11 refs

Key Words: Interaction: rotor-foundation, Rotors, Foundations, Electric systems

Turbo-generator shafts and foundations are transiently excited by electrical system faults like terminal short circuits, faulty synchronizing, clearing of network short circuits near to the power plant. Abnormal mechanical stressing in rotor and foundation is caused by pulsating electromagnetic forces. They have to be taken into account by dynamic stress investigations of both structures. An accurate determination of local stress values demands complex mathematical models (FEM) and time-consuming numerical investigations (time-history-method) in order to solve the equations of motion. A large FEM-modeled turbo-shaft and foundation were treated by the exact but time-consuming time-history-method and the response-spectra-method as an economical method of approximation considering the dynamic character of the problem. In addition, the dynamic stress of foundations was evaluated by a quasi static analysis according to the old German Standard DIN 4024.

81-2531

Seismic Response of a Flexible Rotor

T. Shimogo and M. Nakano

Keio Univ., Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 321-326, 20 figs, 4 tables, 4 refs

Key Words: Rotors, Flexible rotors, Seismic response

The results of seismic response analysis of a flexible rotor supported by two bearings, in which the dynamic properties are represented by linear springs and dampers, are presented. For the simplification of a theoretical treatment the rotor is represented as either a lumped or a uniformly distributed parameter system, and gyroscopic moments are included. The seismic excitations acting on two bearings are assumed to be a stationary Gaussian random process with a dominant frequency such as the El Centro earthquake waveform. In particular, the influences of a flexibility of rotor upon the seismic responses; i.e., the relative displacement of the rotor, the dynamic loading of the bearings, and so on, are studied. Numerical examples of a generator-rotor of 350MW steam power plant indicate the fact that the maximum r.m.s. responses are considerably bigger than those obtained on the assumption of a rigid rotor, due to a decreasing fundamental resonance frequency. Influence of rotor speed on the seismic response is also examined.

81-2532

Dynamics of High Speed Rotative Assemblies

D.A. Thurgood

British Aerospace Dynamics Group, Hatfield Div., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 389-393, 7 figs, 1 table, 1 ref

Key Words: Compressors, Rotary compressors, Turbomachinery, Balancing techniques, Damping

Presentation is made of the development experience of a series of high speed turbocompressor units for aircraft air-conditioning systems with particular reference to aspects of balancing, shaft response and damping, and excitations from angular contact ball bearings.

81-2533

Analysis and Design of Centrifugal Pumps Considering Rotor Dynamics

M. Takagi, O. Matsushita, T. Ino, K. Kikuchi, and K. Komatsu

Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 43-51, 16 figs, 1 table, 11 refs

Key Words: Pumps, Centrifugal pumps, Friction excitation

In this paper rotational bending stress analysis of centrifugal pump rotors, imbalance response analysis, stability analysis of self-excited vibration and unsteady response analysis due to rubbing are developed. Systematic tests corresponding to these analyses are carried out using actual multi-stage centrifugal pumps. The calculated values agreed well with the experimental values with regard to the stability-threshold speed, and the steady state rotational bending stresses. Qualitative agreement was obtained with regard to the behavior of transient stress due to rubbing. On the basis of these results, methods of estimating the vibration responses and bending stresses in the high speed large-scale multi-stage centrifugal pumps, and pump design methods considering these factors are established.

RECIPROCATING MACHINES

81-2534

Energy Conservation and Noise Control in Pneumatic Devices and Systems, Part II - Percussive Tools, Blow-offs and Air Ejectors

M.D. Oviatt

Richard K. Miller & Associates, Inc., Alpharetta, GA, Plant Engineering, 35 (16), pp 116-118 (Aug 6, 1981) 2 figs

Key Words: Hand tools, Noise reduction

Noise reduction techniques of hand held reciprocating tools, such as chipping hammers, needle scalars, sand rammers, rock drills, pavement-breakers, blow-off nozzles, and air ejectors, are presented.

METAL WORKING AND FORMING

(See No. 2664)

STRUCTURAL SYSTEMS

BUILDINGS

(Also see Nos. 2561 and 2691)

81-2535

The Tenth Sir Richard Fairey Memorial Lecture: Sound Transmission in Buildings

M. Heckl

Institut f. Technische Akustik, Technische Universität Berlin, D-1000 Berlin 10, Germany, J. Sound Vib., 77 (2), pp 165-189 (July 22, 1981) 22 figs, 2 tables, 27 refs

Key Words: Buildings, Sound transmission

Sound transmission through walls, ceilings, windows, doors, etc., depends on (1) mass per unit area, (2) bending stiffness, (3) damping, (4) variation in bending stiffness (because of struts or other anisotropies), (5) stiffness and damping of interlayers and sound bridges (in cases of double walls), (6) size and shape of partitions, (7) mounting conditions, (8) influence of flanking walls, (9) unwanted effects such as slits, etc. The first three parameters and to a certain degree also the fourth and fifth can be dealt with theoretically by investigating walls of infinite size. In this way many of the results obtained in buildings can be explained at least qualitatively. The influences of size, shape, mounting conditions and the influence of flanking transmission can be understood best by applying energy balance equations, and in this way the average behavior of reasonably large constructions can be explained.

81-2536

Approximate Method for Lateral Load Analysis of High-Rise Buildings

F.K.E.C. Mortelmans, G.P.J.M. de Roeck, and D.A. Van Gemert

Struct. Engrg. Dept., Katholieke Universiteit Leuven, Belgium, ASCE J. Struc. Div., 107 (ST8), pp 1589-1610 (Aug 1981) 16 figs, 1 table, 7 refs

Key Words: Framed structures, Multistory buildings, Buildings, Wind-induced excitation, Columns

An approximate method for the design of long, high-rise buildings under horizontal wind loading is described. The method is based on the reduction of the framed structure to one built-in column with equivalent bending and torsional stiffnesses. Discrete actions of the horizontal members on the columns are distributed over the story heights. The floors are treated as rigid in the horizontal plane. The calculation is reduced to the solution of a system of four linear equations; the determination of internal actions only requires some very simple operations. The accuracy of the method is demonstrated by comparison to the displacement method.

81-2537

Torsional Coupling and Earthquake Response of Simple Elastic and Inelastic Systems

C.L. Kan and A.K. Chopra

Dept. of Civil Engrg., Univ. of California, Berkeley, CA, ASCE J. Struc. Div., **107** (ST8), pp 1569-1588 (Aug 1981) 16 figs, 1 table, 8 refs

Key Words: Buildings, Earthquake response, Torsional response, Lateral response

The effects are analyzed of torsional coupling on the earthquake response of simple one-story structures in elastic and inelastic ranges of behavior. The structures considered are symmetrical about one principal axis of resistance, resulting in coupling only between lateral displacement along the perpendicular axis and the torsional displacement. Torsional coupling arising only from eccentricity between centers of mass and elastic resistance is considered. Systems with several resisting elements are idealized by a single element model. Response of such a model to a selected earthquake ground motion are presented for a range of the basic structural parameters. The response quantities presented include maximum lateral and torsional deformations of the system as well as maximum deformations of individual columns. The response in the inelastic range of behavior is effected by torsional coupling to generally a lesser degree than elastic response.

TOWERS

81-2538

Measurements of Wind and Deformation on a High Radio Tower. Part 3. Measurement (Wind- und Verformungsmessungen an einem Funkturm. Teil 3. Messungen)

W. Neuerburg

Maschinenlaboratorium 2 der Fachhochschule für Technik Esslingen, Kanalstr, Esslingen, Germany, Techn. Messen-ATM, 7/8, pp 275-280 (July/Aug 1981) 13 figs, 1 ref
(In German)

Key Words: Towers, Wind induced excitation, Experimental test data

The wind loadings on a high tower structure and the coherent effects of static and dynamic responses were studied by means of versatile measurement equipment. Wind pressures against the tower wall, the deformation and oscillation of the structure and the free-streaming wind were measured with reference to the time.

FOUNDATIONS

(Also see Nos. 2527, 2529, 2530)

81-2539

Plastic Models in Turbomachinery Foundation Studies

R.L. Bannister and J.K. Aneja

Westinghouse Electric Corp., Lester, PA, ASCE J. Engr. Mech. Div., **107** (EM4), pp 649-667 (Aug 1981) 13 figs, 1 table, 22 refs

Key Words: Turbomachinery, Machine foundations, Resonant frequencies, Mode shapes, Experimental test data, Model testing

Over a period of years, the static and dynamic behavior of turbomachinery foundations have been studied with scaled plastic models. Experimental data from several investigators show the type of information that can be obtained for resonant frequencies, mode shapes and response levels in the laboratory. Model test data are compared with measurements made on full-size structures and also calculated from analytical models. Accuracy is dependent on the degree to which similitude requirements are met. Experimental results are also presented to show how structural models have been used to determine the effect of foundation termination, rotor unbalance and bearing support stiffness.

UNDERGROUND STRUCTURES

81-2540

Numerical Simulations of Earthquake Effects on Tunnels for Generic Nuclear Waste Repositories

K.K. Wahi, B.C. Trent, D.E. Maxwell, R.M. Pyke, and C. Young

Science Applications, Inc., Fort Collins, CO, 132 pp (Dec 1980)
DP-1579

Key Words: Underground structures, Tunnels, Nuclear waste depositories, Rocks, Seismic waves, Earthquake response, Numerical analysis

The objectives of this generic study were to use numerical modeling techniques to determine under what conditions seismic waves generated by an earthquake might cause instability to an underground opening, or cause fracturing and joint movement that would lead to an increase in the permeability of the rock mass. Three different rock types (salt, granite, and shale) were considered as host media for the repository located at a depth of 600 meters. Special

material models were developed to account for the nonlinear material behavior of each rock type. The sensitivity analysis included variations in the in situ stress ratio, joint geometry, pore pressures, and the presence or absence of a fault. Three different sets of earthquake motions were used to excite the rock mass.

HARBORS AND DAMS

81-2541

Earthquake Analysis of Concrete Gravity Dams Including Dam-Water-Foundation Rock Interaction
A.K. Chopra and P. Chakrabarti
Univ. of California, Berkeley, CA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 363-383 (July-Aug 1981) 9 figs, 1 table, 19 refs

Key Words: Dams, Concretes, Earthquake damage, Interaction: structure-fluid

A general procedure for analysis of the response of concrete gravity dams, including the dynamic effects of impounded water and flexible foundation rock, to the transverse (horizontal) and vertical components of earthquake ground motion is presented. The problem is reduced to one in two dimensions, considering the transverse vibration of a monolith of the dam. The system is analyzed under the assumption of linear behavior for the concrete, foundation rock and water. The complete system is considered as composed of three substructures -- the dam, represented as a finite element system, the fluid domain, as a continuum of infinite length in the upstream direction, and the foundation rock region as a viscoelastic half-plane. The structural displacements of the dam are expressed as a linear combination of Ritz vectors, chosen as normal modes of an associated undamped dam-rock system. The effectiveness of this analytical formulation lies in its being able to produce excellent results by considering only a few Ritz vectors. The generalized displacements due to earthquake motion are computed by synthesizing their complex frequency responses using Fast Fourier Transform procedures. The stress responses are calculated from the displacements. An example analysis is presented to illustrate results obtained from this analytical procedure. Computation times for several analyses are presented to illustrate the effectiveness of the procedure.

81-2542

Simulation of Strong Earthquake Motion with Contained-Explosion Line Source Arrays, Report on Task 6: Feasibility of Earth Dam Testing
P.N. Agrawal and J.R. Bruce

SRI International, Menlo Park, CA, Rept. No. NSF/RA-800421, 50 pp (Sept 1980)
PB81-174096

Key Words: Dams, Dynamic tests, Earthquake simulation

This study explores the feasibility, scope, and cost of dynamic testing of earth and rock-filled dams using explosives to generate the required earthquake-like ground motions. It was concluded that the response of dams to high-level sustained earth shaking, representative of actual earthquakes, can be investigated with explosive array techniques. The dams should be of small to moderate size and should be constructed in a special field test site with moderately strong native soil (not rock). Earth shaking would be provided by contained-explosion arrays that can produce the high-level sustained motion in repeated tests without replacement. It was also concluded that application of strong motion from explosive arrays is not practical because of the risk of damage to the dam or its surroundings.

81-2543

Hydrodynamic and Foundation Interaction Effects in Earthquake Response of a Concrete Gravity Dam
A.K. Chopra and S. Gupta
Univ. of California, Berkeley, CA, ASCE J. Struc. Div., 107 (ST8), pp 1399-1412 (Aug 1981) 15 figs, 3 tables, 8 refs

Key Words: Dams, Concretes, Earthquake response

The displacement and stress responses are presented for Pine Flat Dam to the S69E component of the Taft ground motion only, and to the S69E and vertical components acting simultaneously. For each of these excitations, the response of the dam is analyzed four times corresponding to the following four sets of assumptions: (a) Rigid foundation, hydrodynamic effects excluded; (2) rigid foundation, hydrodynamic effects included; (3) flexible foundation, hydrodynamic effects excluded; and (4) flexible foundation, hydrodynamic effects included. Based on these results, the separate effects of dam-water interaction and dam-foundation rock interaction, and the combined effects of the two sources of interaction, on earthquake response of dams are investigated.

CONSTRUCTION EQUIPMENT

81-2544

Evaluation of Vibratory Rollers for Bomb Damage Repair
K.J. Knox

Engrg. and Services Lab., Air Force Engrg. and Services Ctr., Tyndall AFB, FL, Rept. No. AFESC/ESL-TR-80-43, 71 pp (Aug 1980)
AD-A096 534

Key Words: Compactors, Vibratory techniques, Vibratory tools, Airports

Four vibratory rollers in the 8.5 to 17-ton range were evaluated for use in bomb damage repair of airfields. The rollers were tested for their compaction ability on grade crushed limestone. After this initial testing the two most promising rollers were tested by repairing simulated bomb craters using 24-inch thick layers of crushed limestone compacted only from the surface. These repairs were tested with F-4 load-craft traffic.

81-2545

Effect of Barriers on Propagation of Construction Noise

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-113, 147 pp (Dec 1980)

PB81-166829

Key Words: Construction equipment, Noise barriers

The study reported is primarily concerned with investigating the effect of barriers on propagation of construction equipment noise and to examine the suitability of some of the more recent and widely used barrier theories. In addition, this study investigates the attenuation afforded by real sized cuttings and embankments with controlled loudspeaker sound source.

81-2546

Measurement and Prediction of Construction Plant Noise

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-112, 230 pp (Sept 1980)

PB81-166837

Key Words: Construction equipment, Noise prediction, Noise measurement

The purpose of this report is to summarize the results of a study concerned with the prediction and measurement of noise exposure levels from construction machinery on a site. The relevance of this subject is illustrated by reference to national and international standards and legislation. This study was consummated through the development and validation of prediction and measurement methodologies by considering the following topics: propagation characteristics of noise from stationary and mobile sources over realistic ground surfaces; directivity patterns of noise from construction equipment; transmission of loss characteristics by a building facade; and noise monitoring from construction sites.

81-2547

Assessment and Propagation of Noise from Conventional and 'Quiet' Pile Drivers

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-110, 184 pp (Sept 1980)

PB81-168866

Key Words: Pile drivers, Noise generation, Sound propagation

This report summarizes the results of a study aimed at defining some of the important basic characteristics of noise from conventional pile drivers, which are considered to be one of the most significant sources of noise annoyance in the community during civil engineering projects, and a range of pile driving devices which were either adapted or designed specifically to generate noise levels below those normally expected from conventional impact pile drivers. The parameters studied were noise levels, spectra and waveform shapes. This study has shown that recent legislation and other stimuli have resulted in a range of pile driving devices whose use, where circumstances permit, results in 10 to 40 dB(A) lower equivalent sound levels being generated by the extensively treated piling rigs as compared with the conventional untreated piling rigs, these reduced noise levels being equal to or less than that produced by other construction site noise sources. In addition, this study investigates the propagation characteristics of noise from pile drivers and also indicates how the noise from such a source is affected by the interposition of a barrier.

POWER PLANTS

81-2548

Noise Prediction for Fossil Fuel Power Plants

S. Shimode and H. Fujita

Mech. Engrg. Res. Lab., Hitachi, Ltd., Tsuchiura, Ibaraki, Japan, Noise Control Engrg., 17 (1), pp 22-29 (July-Aug 1981) 12 figs, 2 tables, 14 refs

Key Words: Fossil power plants, Electric power plants, Industrial facilities, Noise reduction

Noise control for large plants is one of the major pollution problems in Japan. Development of a technology for reliable prediction of the noise field for such plants is described. Characteristics of both sound sources and propagation paths are discussed in detail, mainly in reference to turbine housings of fossil fuel power plants. Comparison of the predicted noise field of a power plant with actual measurement showed good agreement and confirmed the usefulness of the prediction program developed.

81-2549

Response of a Thermal Barrier System to Acoustic Excitation in a Gas Turbine Nuclear Reactor

W.S. Betts, Jr. and R.D. Blevins

General Atomic Co., San Diego, CA, Rept. No. CONF-810309-7, 11 pp (Nov 1980)

GA-A-16016

Key Words: Nuclear reactors, Thermal insulation, Acoustic excitation, Vibration analysis

A gas turbine located with a high-temperature gas-cooled reactor induces high acoustic sound pressure levels into the primary coolant (helium). This acoustic loading induces high cycle fatigue stresses which may control the design of the thermal barrier system. This study examines the dynamic response of a thermal barrier configuration consisting of a fibrous insulation compressed against the reactor vessel by a coverplate which is held in position by a central attachment fixture. The results of dynamic vibration analyses indicate the effect of the plate size and curvature and the attachment size on the response of the thermal barrier.

OFF-SHORE STRUCTURES

81-2550

Parameter Adjustment of a Model of an Offshore Platform from Estimated Eigenfrequencies Data

H. Natke and H. Schulze

Curt-Risch-Institut f. Schwingungs- und Messtechnik, Universität, Hannover, D-3000 Hannover 1, Fed.

Rep. Germany, J. Sound Vib., 77 (2), pp 271-285 (July 22, 1981) 7 figs, 2 tables, 16 refs

Key Words: Off-shore structures, Drilling platforms, Parameter identification techniques, Damping coefficients

A full scale dynamic test which was incomplete because of rough seas and bad weather conditions and a computational model of the research platform "Nordsee" were the starting points of the work described in this paper. The transient excitation used in the test produced vibrations in the lower frequency range with certain identifiable eigenfrequencies and damping ratios. The identified eigenfrequencies were used as the basis for mass adjustment of the computational model. The computational model consists of a 176 degrees of freedom system, in which the flexible constraints and the virtual mass of water are neglected. The most uncertain data were the masses of the deck body. Parameter sensibility investigations, and a priori knowledge of the system and the test conditions led to an adjustment of the mass matrix partitioned corresponding to subsystems. The adjustment was carried out in a factorial global way, in respect to the defined subsystems. The result is an optimum model corresponding to the chosen loss function; the residuum used concerns the inverse eigenfrequency.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 2564, 2565, 2653, 2684, 2685, 2686)

81-2551

Analyzing Noise with Finite Elements

Machine Des., 53 (18), pp 148-153 (Aug 6, 1981)
1 ref

Key Words: Motor vehicle noise, Automobiles, Noise generation, Finite element technique

The use of the finite element technique to study noise propagation in intricate cavities is demonstrated by applying it in the analysis of an automobile compartment boom noise. Such noise is produced by cavity resonance excited by wind, loading engine vibration and road roughness. Results of the analysis show that seat shape has a significant effect on cavity resonance, suggesting that some design change may eliminate the booming phenomena.

81-2552

Reduction of Combustion Noise and Structural Improvement of Its Transmission Path in Diesel Engine Design

Y. Watanabe

Nissan Diesel Motor Co., Ltd., Ageo-shi, Japan, Intl. J. Vehicle Des., 2 (3), pp 276-288 (1981) 15 figs, 2 tables, 3 refs

Key Words: Trucks, Diesel engines, Noise reduction, Structural modification effects

In order to provide a quieter diesel engine as an essential component of low-noise trucks, a two-year investigation of combustion noise and engine structural analysis was carried out. Influences of various variables related to combustion noise were observed on a Vee type two-cylinder engine, and the variables which seemed to be effective for noise control were confirmed on a multi-cylinder engine. Structural analysis was advanced by using improved measuring techniques such as applications of laser holography, transfer function and F.F.T. Furthermore, the adoption of accelerated running simulation on an eddy-current dynamometer made noise evaluation possible in an engine operating condition that was close to the actual vehicular situation. The target figure of engine noise reduction, 2 to 4 dB(A), could be almost achieved by cylinder block structural modification and turbocharging or by increasing the compression ratio for N.A. engines. Engine noise control techniques found to be effective and their problems are also discussed.

81-2553

Analysis of Wheel Rail Force and Flange Force During Steady-State Curving of Rigid Trucks

H. Weinstock and R. Greif

Transportation Systems Ctr., Cambridge, MA, ASME Paper No. 81-RT-5

Key Words: Trucks, Interaction: rail-wheel

The wheel/rail forces and flange forces resulting from steady-state curve negotiation are developed through analysis of a rigid two-axle truck. The analysis provides closed form relations for estimating wheel/rail forces, flange forces, truck angle of attack and sliding conditions for this type of truck as a function of curve radius. The wheel profiles are modeled by conical wheel treads with vertical wheel flanges and flange friction effects are included. The theory used includes both linear and nonlinear creep.

81-2554

An Application of Stereoscopic Techniques Using

Mobile High-Speed Cameras in Automotive Crash Simulation

A. Lozzi and J. Chapman

Dept. of Mech. Engrg., Univ. of Sydney, Australia, Intl. J. Vehicle Des., 2 (3), pp 299-307 (1981) 6 figs, 3 refs

Key Words: Collision research (automotive), Photographic techniques

Parallel axis stereophotography has been applied to record events of an automotive crash simulation. Two 16 mm, high frame rate, high acceleration cameras were used of the type developed for use on board military aircraft. The cameras travelled with the crashing vehicle, and were mounted on a rigid frame which was in turn attached to the floor pan of the vehicle. The crashes referred to here simulated car-to-pole side impacts. The cameras provided a stereoscopic record of events within the body shell's interior during the impact. Displacements and velocities of the anthropomorphic dummies seated in the body shell and of the intrusion caused by the pole, were determined using a single stereo photogrammetric method. Depth measurements were obtained with relative errors of about 1%, or 15 mm.

SHIPS

(See No. 2629)

AIRCRAFT

(Also see No. 2622)

81-2555

Structure-Borne Noise Prediction for a Single-Engine General Aviation Aircraft

J.F. Unruh

Southwest Res. Inst., San Antonio, TX, J. Aircraft, 18 (8), pp 687-694 (Aug 1981) 13 figs, 1 table, 9 refs

Key Words: Aircraft noise, Structure-borne noise, Interior noise, Noise prediction, Finite element technique

The usefulness of a deterministic modeling procedure employing structural-acoustic finite-element formulations is investigated for the prediction of structure-borne interior noise. Analytical predictions are compared to normal mode, forced harmonic response, and engine-running experimental data obtained during ground tests of a single-engine general aviation aircraft. From these comparisons, the modeling procedures are shown to be sufficiently accurate for structure-borne interior noise prediction.

81-2556

An Optimization Method for the Determination of the Important Flutter Modes

E. Nissim and I. Lottati

Technion - Israel Inst. of Tech., Haifa, Israel, J. Aircraft, 18 (8), pp 663-668 (Aug 1981) 11 figs, 4 tables, 9 refs

Key Words: Aircraft, Flutter, Optimization

An optimization method for the determination of the dominant flutter modes is presented in this paper. The method is based on the minimization of the quadratic values of sub-determinants derived from the equations of motion. The effectiveness of the method is illustrated by seven numerical examples.

81-2557

Forced Backward Whirling of Aircraft Propeller-Engine Systems

S.H. Crandall and J. Dugundji

Massachusetts Inst. of Tech., Cambridge, MA, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 265-270, 5 figs, 4 refs

Key Words: Aircraft engines, Propellers, Propeller blades, Whirling

Transverse excitation of a light aircraft engine block by the sequential firing of the cylinders can excite a natural mode of vibration which involves backward whirling of the engine at the excitation frequency and propeller blade vibration at a frequency that is the sum of the excitation frequency and the engine speed. The phenomenon is explained in terms of a simplified model with only two non-trivial degrees of freedom.

81-2558

Crashworthiness Design Parameter Sensitivity Analysis

A.E. Tanner

Boeing Vertol Co., Philadelphia, PA, Rept. No. USAAVRADCOM-TR-80-D-31, 281 pp (Feb 1981) AD-A096 550

Key Words: Aircraft, Crash research (aircraft), Crashworthiness, Design techniques

This program investigated the relationships between aircraft weight, the level of crashworthiness in the design, and the cost and weight associated with crashworthiness elements of the design. Accident and research data were reviewed and actual aircraft designs were analyzed with respect to their levels of crashworthiness and potential improvements. Processing of the data yielded cost and weight curves for use in preliminary design. The curves provide the relationships between gross weight, mean empty weight, levels of crashworthiness, and selected design elements that contribute to crashworthiness for designs employing metallic or composite materials and having gross weights up to 50,000 pounds. Comparisons were made with the current ACAP analyses and results showed good agreement for the weight values and level of crashworthiness.

81-2559

Development of Advanced Techniques for Rotorcraft State Estimation and Parameter Identification

W.E. Hall, Jr., J.G. Bohn, and J.H. Vincent
Systems Control, Inc., (VT), Palo Alto, CA, Rept. No. NASA-CR-159297, 265 pp (Nov 1980) N81-19098

Key Words: Helicopters, Parameter identification techniques

An integrated methodology for rotorcraft system identification consists of rotorcraft mathematical modeling, three distinct data processing steps, and a technique for designing inputs to improve the identifiability of the data. These elements are as follows: (1) a Kalman filter smoother algorithm which estimates states and sensor errors from error corrupted data. Gust time histories and statistics may also be estimated; (2) a model structure estimation algorithm for isolating a model which adequately explains the data; (3) a maximum likelihood algorithm for estimating the parameters and estimates for the variance of these estimates; and (4) an input design algorithm, based on a maximum likelihood approach, which provides inputs to improve the accuracy of parameter estimates. Each step is discussed with examples to both flight and simulated data cases.

MISSILES AND SPACECRAFT

81-2560

Seismic Hazards Studies for Minuteman Missile Wings
J.C. Battis

Air Force Geophysics Lab., Hanscom AFB, MA,
Rept. No. AFGL-TR-80-0293, 73 pp (Sept 9, 1980)
AD-A096 720

Key Words: Missiles, Seismic response

Using standard methods of probabilistic seismic risk analysis, estimates of the seismic hazards for six Minuteman missile wings were evaluated. For each site, estimates of the site intensity, acceleration, velocity and displacement annual risk curves were made based on the historical seismicity within 1000 km of each site. Based on these curves, composite design response spectra for 10-, 100-, and 1000-year return period motions were calculated. Plots of the reported earthquake epicenters near each site were also generated. To conduct these studies, a new method for regional modification of peak acceleration attenuation functions was developed and is presented in the appendix to this report.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

(Also see No. 2568)

81-2561

Seismic Effectiveness of Tuned Mass Dampers

A.M. Kaynia, D. Veneziana, and J.M. Biggs
Massachusetts Inst. of Tech., Cambridge, MA, ASCE
J. Struc. Div., 107 (ST8), pp 1465-1484 (Aug 1981)
11 figs, 1 table, 22 refs

Key Words: Tuned dampers, Single degree of freedom systems, Earthquake response, Buildings

Time history analysis of one degree of freedom systems with and without a tuned mass damper, subjected to a set of historical earthquakes, shows that the peak response ratio (ratio between the peak responses with and without damper) depends primarily on damping constants and on earthquake duration. The same analysis reveals that response ratio values are widely scattered and that the mean response ratio is underestimated by conventional stationary random vibration calculations. Improvement is obtained by considering response movement and broadening of the response spectral density function caused by the damper. Based on these considerations, a probabilistic model is developed that gives the distribution of peak response of buildings modified by addition of a tuned mass damper in terms of the same distribution for the unmodified structures.

81-2562

Avoiding Compromise in Engine Mounting

R. Racca

Barry Controls, Barry Wright Corp., Diesel Progress
North American, 47 (8), pp 34-36 (Aug 1981)

Key Words: Mountings, Engine mounts

The author stresses the importance of proper mounting of an automobile engine, requiring a good understanding of the effect of dynamic loads on the engine. A dynamic analysis procedure is described.

81-2563

Design and Performance of Resonant-Cavity Parallel Baffles for Duct Silencing

P.T. Soderman

U.S. Army Research and Technology Lab., Ames
Res. Ctr., Moffett Field, CA, Noise Control Engrg.,
17 (1), pp 12-21 (July-Aug 1981) 18 figs, 1 table,
25 refs

Key Words: Silencers, Baffles, Ducts, Noise reduction

To control noise emission from large ducts, designers often choose some variation of parallel baffles filled with fibrous material. The acoustic performance of such silencers can be very good, but in severe environments they are susceptible to clogging, erosion and settling. There is an alternative - resonant-cavity parallel baffles. This type of baffle, either empty or with a thin absorbent lining pinned to an internal septum, is virtually immune to the above problems. An analytical and experimental study of resonant-cavity baffle silencers, including comparisons with fiberglass-filled baffles, is described.

81-2564

Fundamental Study on Semi-Actively Controlled Pneumatic Servo Suspensions for Rail Cars

K. Jindai, K. Kasai, K. Terada, Y. Kakehi, and F. Iwasaki

Japanese Natl. Railways, Tokyo, Japan, ASME Paper
No. 81-RT-6

Key Words: Railroad cars, Suspension systems (vehicles), Semiactive isolation

Semi-actively controlled suspension systems were devised to reduce the vibrations of railroad passenger cars. Two

vertical and one lateral pneumatic servo cylinders were mounted parallel to the air springs on each truck. The acceleration signal of the car body above each cylinder was transferred independently to each controller, and the vertical and lateral controllers were adjusted to approximate the results of the optimum analysis of vertical vibration mode and yawing mode respectively.

81-2565

An Experimental Comparison Between Semi-Active and Passive Suspensions for Air-Cushion Vehicles

D. Hrovat and D.L. Margolis

Dept. of Mech. Engrg., Wayne State Univ., Detroit, MI, Intl. J. Vehicle Des., 2 (3), pp 308-321 (1981) 9 figs, 2 tables, 15 refs

Key Words: Suspension systems (vehicles), Ground effect machines, Dampers, Active damping, Semiactive isolation, Passive isolation

An experimental heave mode model of a tracked air cushion vehicle incorporating on-off semi-active (SA) damper suspension is described. Preliminary tests are conducted to assess the SA pneumatic damper characteristics. For identical sinusoidal ground inputs, the totally passive and on-off SA damping schemes are compared in terms of sprung mass vibration isolation properties. It is shown that the semi-active suspension offers significant advantages over the corresponding passive suspensions, while at the same time requiring only a small amount of control energy.

BLADES

81-2566

Further Studies of Bladed Disc Vibration: Effects of Packeting

D.J. Ewins

Imperial College of Science and Tech., London, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 97-102, 5 figs, 12 refs

Key Words: Blades, Turbomachinery, Tuning

Various studies made in recent years of the effects of blade mistuning on the vibration characteristics of turbomachine bladed disc assemblies have provided an understanding and

explanation of many of the complex blade vibration phenomena observed under operating conditions. The concepts and techniques introduced in those studies have now been further developed to explore a new range of conditions; namely, where the 'mistuning' is no longer 'small' and is introduced deliberately. Such conditions prevail in bladed assemblies where the blades are grouped in packets either for convenience of assembly (as in steam turbines) or in order to induce a significant detuning of a certain assembly mode. The characteristics of such assemblies are described and their relationship to the corresponding properties of a symmetrical or tuned system established, since the computational effort required to analyze a packeted bladed disc is very much greater than for its continuously-shrouded counterpart.

81-2567

Stall Flutter of Linear Cascade in Compressible Flow

S. Kaji

Univ. of Tokyo, Tokyo, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 209-214, 6 figs, 5 refs

Key Words: Cascades, Jet engines, Fans, Flutter

Stall and non-stall bending mode flutter in high subsonic and supersonic flows is analyzed by the semi-actuator disc theory. Transonic two-dimensional cascade test data are used for the estimation of total pressure-loss change due to airfoil oscillation. Occurrence of 'resonance flutter' which is different from usual stall flutter is predicted. This flutter arises near the cascade resonance conditions for highly loaded cascades in high Mach number flows. Flutter boundaries obtained for subsonic flows and supersonic flows show quite different variations against the change in flow incidence. It is also shown that the direction of airfoil oscillation has a significant effect on flutter boundaries.

BEARINGS

(Also see Nos. 2506, 2527, 2659, and 2670)

81-2568

Gyroscopes with Ball Bearing Suspension

V.F. Zhuravlev and D.M. Klimov

Inst. for Problems in Mechanics, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 367-368, 1 fig, 3 refs

Key Words: Bearings, Ball bearings, Gyroscopes, Vibration analysis

Ball bearing suspension, which is often used in gyroscopic devices, constitutes a complex system of many elastic bodies (balls, rings, retainers). Special coordinates introduced allow calculation of the potential energy of gyroscopic systems taking into account all possible imperfections in ball bearings. The linear equations of motion of rotor in nonideal ball bearings derived define the spectrum and the level of vibration. The nonlinear equations allow discovery of a few fine phenomena (such as impossibility of exact balancing of rotor in nonideal ball bearings, etc.).

81-2569

Experimental Study of an Inter-Shaft Squeeze Film Bearing

J.B. Courage

Rolls Royce, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 375-380, 10 figs, 8 refs

Key Words: Bearings, Rolling contact bearings, Squeeze-film dampers

The application of squeeze films to the static outer races of rolling element bearings is now common practice in gas turbine engines. However many engines also feature inter-shaft bearings where the benefits of squeeze films could be equally significant. This paper describes an experimental program that has been carried out on a model twin shaft rig to evaluate the feasibility of such a device.

81-2570

Rubber Surface Squeeze Film

Y. Hori, T. Kato, and H. Narumiya

Dept. of Mech. Engrg., The Univ. of Tokyo, Bunkyo-ku, Tokyo, Japan, J. Lubric. Tech., Trans. ASME, 103 (3), pp 399-405 (July 1981) 13 figs, 10 refs

Key Words: Bearings, Squeeze film bearings, Elastomers, Low frequencies, High frequency excitation

Numerical solutions for the squeeze film problem, in which one of the surfaces is made of rubber and moves sinusoidally, are presented. Viscoelasticity and incompressibility of the rubber are taken into account in the numerical procedures. The solutions agree well with the experiments. Variation of the squeeze film shape with time is measured by the moiré

topography. This will be one of the best methods for measuring the film thickness when the lubricating surface is made of soft materials like rubber.

81-2571

Some Damping and Stiffness Characteristics of Angular Contact Bearings under Oscillating Radial Load

T.L.H. Walford and B.J. Stone

Bearing Res. Ctr., Newark, Notts, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 157-162, 4 figs, 2 tables, 4 refs

Key Words: Bearings, Rolling contact bearings, Damping coefficients, Stiffness coefficients, Lubrication

Damping and stiffness measurements are presented for a pair of angular contact bearings which show damping increasing and stiffness decreasing as oil viscosity is reduced. A theoretical model is presented which indicates that the stiffness of the interfaces, between the races and the housing and shaft, is a very significant parameter and is the cause of the observed effect.

81-2572

Magnetic Bearings - A Novel Type of Suspension

G. Schweitzer and H. Ulbrich

Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 151-156, 10 figs, 12 refs

Key Words: Bearings, Magnetic bearings, Rotors

It is well known that a rotor can be supported without contact and without wear by suitable electromagnetic forces. The technical implementation of the basic idea, however, is still rather uncommon. By means of examples the state of the art and possible future trends of the theory and the application of magnetic bearings are demonstrated. One example, the full magnetic suspension of a centrifuge in a vacuum tube, is treated comprehensively.

81-2573

An Instrument for the Measurement of Long-Term

Variations of Vertical Bearing Alignments in Turbo-generators

A. Clapis, G.L. Lapini, and T. Rossini
Centro Informazioni Studi Esperienze, Milano, Italy,
Vibrations in Rotating Machinery, Proc. 2nd Intl.
Conf., Churchill College, Cambridge, UK, Sept 1-4,
1980, organized by Instn. Mech. Engrs., pp 119-124,
10 figs, 3 refs

Key Words: Bearings, Turbogenerators, Alignment, Measurement techniques

A special instrument, called ADE, is described, purposely developed to measure the long-term variations of vertical bearing alignments in turbogenerators. The instrument is based on the communicating vessel principle. A proper number of interconnected cups containing mercury are attached to the machine supports. The liquid level variations in the cups, due to their vertical movements, are measured by proximity transducers fixed on the cup tops. The paper presents a summary of results from measurements by the ADE system on two large turbogenerators where the alignment changes have caused vibration problems.

81-2574

Generation of Squeal/Chatter in Water-Lubricated Elastomeric Bearings

A.I. Krauter
Tech. Dept., Shaker Research Corp., Ballston Lake,
NY, J. Lubric. Tech., Trans. ASME, 103 (3), pp
406-413 (July 1981) 7 figs, 3 tables, 5 refs

Key Words: Bearings, Elastomeric bearings, Chatter

This paper presents results from an investigation concerned with vibrational characteristics of compliant-layer water-lubricated bearings. An experimental apparatus emulates the dynamic interactions between the propeller shaft and a water-lubricated elastomeric bearing stave. A computer model predicts the squeal tendency of the experimental apparatus. Correlations are obtained by using the apparatus to verify the predicted squeal tendency. Utilizing the computer model, the effects of varying system parameters on squeal/chatter are determined quantitatively. From the results obtained, it is found that the slope of the friction-speed curve and the effective structural damping are the most important parameters. It is concluded that the essential features of squeal/chatter have been identified and that the phenomenon can be modeled analytically.

81-2575

Dynamically Tuned Gyroscopes and Their Spin Axis Bearings

D.G. Bonfield and D.J. Haines

Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 327-332, 3 figs, 3 tables, 5 refs

Key Words: Bearings, Gyroscopes, Tuning

British Aerospace work on rotor restraint and vibration problems which can limit dynamically tuned gyroscope performance is discussed. The work has resulted through careful design, development and control of critical parts in a series of dynamically tuned gyroscopes to meet missile, aircraft and ship guidance requirements. Gyro rotors mounted on a single gimbal and subject to excitation may now be trimmed to a drift rate of less than $0.1^\circ/\text{hour}$. For other applications a double gimballed, two axis free rotor unit has been developed in which a number of torsion flexing hinged elements are arranged in a manner similar to two interlaced Hooke's joints but where the freely pivoting hinges of the latter are replaced by torsion cross leaf springs and the intermediate frame members of the couplings act as dynamic gimbals. Drift rates of much less than the above are achieved with these units.

81-2576

Effects of Vibrations Generated by Spin Axis Bearings on Gyroscopic Northfinding Equipment

B.T. Trayner
Stevenage Div., British Aerospace Dynamics Group,
Stevenage, Herts SG1 2DA, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 347-352, 4 figs, 1 table, 3 refs

Key Words: Bearings, Gyroscopes, Beat frequency

The paper outlines a particular problem associated with the production of a first generation northfinder due to beating between the angular velocity of the two cages in the spin axis system. This beat frequency was troublesome when very low (with a period of up to 200 seconds) and very low values appeared with an occurrence rate which was higher than would be predicted by the bearing geometry. The practical solution to the problem which was adopted is given and the influence that this had on the design of a second generation northfinder is discussed.

81-2577

On the Steady State and Dynamic Performance Characteristics of Floating Ring Bearings

C.-H. Li and S.M. Rohde
Mech. Res. Dept., General Motors Res. Labs., Warren,
MI, J. Lubric. Tech., Trans. ASME, **103** (3), pp 389-
397 (July 1981) 18 figs, 13 refs

Key Words: Bearings, Floating ring journal bearings, Journal bearings, Periodic response

An analysis of the steady state and dynamic characteristics of floating ring journal bearings has been performed. The stability characteristics of the bearing, based on linear theory, are given. The transient problem, in which the equations of motion for the bearing system are integrated in real time was studied. The effect of using finite bearing theory rather than the short bearing assumption was examined. Among the significant findings of this study is the existence of limit cycles in the regions of instability predicted by linear theory. Such results explain the superior stability characteristics of the floating ring bearing in high speed applications. An understanding of this nonlinear behavior serves as the basis for new and rational criteria for the design of floating ring bearings.

81-2578

The Effects of Unbalance on Stability and Its Influence on Non-Synchronous Whirling

R.H. Bannister and J. Makdissy
Cranfield Inst. of Tech., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instrn. Mech. Engrs., pp 395-400, 12 figs, 4 refs

Key Words: Bearings, Journal bearings, Hydrodynamic excitation, Whirling, Nonsynchronous vibration

When investigating the behavior of hydrodynamic journal bearings, the criteria for instability is usually defined as a single line on the stability map and no attempt is made to explain the possible working limits between the stable and unstable zones. The work presented is intended as an introduction, explaining the transitional stages of instability and suggests how to estimate the severity of instability by pattern recognition. The influence of nonlinearity of the oil film is also demonstrated, by staging the onset of instability and noting the stabilizing influence made to the bearing for varying magnitudes of unbalance force.

81-2579

On the Dynamic Behaviour of Gyroscopic Systems that Include Oil Lubricated Journal Bearings

H. McCallion and P.M. Ware

Dept. of Mech. Engrg., Univ. of Canterbury, Christchurch, New Zealand, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instrn. Mech. Engrs., pp 133-138, 6 figs, 7 refs

Key Words: Bearings, Journal bearings, Rotors, Shafts, Gyroscopes

Results are reported from a theoretical study into the influences of a number of system parameters on the stability of a family of systems in conical motion. Each member was comprised of a massive rotor, an elastic shaft and a journal bearing. Small oscillations about a steady running position were studied by linearizing the oil film characteristics and it was found that the higher natural frequency could be unstable even when its value was as high as 0.8 times the spin velocity of the shaft. Whirl velocities greater than 0.5 times the spin velocity are not usually associated with oil whip. It is also shown by numerical simulation that some members of this family of systems may be stable at low amplitudes and unstable at high amplitudes and vice versa.

81-2580

Identification of Journal Bearing Coefficients Using a Pseudo-Random Binary Sequence

I.U. Dogan, J.S. Burdess, and J.R. Hewit
Dept. of Mech. Engrg., Univ. of Newcastle upon Tyne, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instrn. Mech. Engrs., pp 277-281, 4 figs, 8 refs

Key Words: Bearings, Journal bearings, Parameter identification techniques, Stochastic processes, Spectrum analysis

A stochastic identification technique based upon spectral analysis has been developed to provide a dynamic model of a journal bearing. An outline of the basic theory is given and the results of experimental work carried out on a laboratory journal bearing are described. Direct and cross transfer functions are derived from the bearing response to pseudo binary excitation and the bearing coefficients determined by optimally fitting theoretical transfer functions to the experimental results.

81-2581

Experimental and Analytical Research on a Full Scale Turbine Journal Bearing

G. Diana, D. Borgese, and A. Dufour

Mechanics of Machinery Inst., Milan, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 309-314, 9 figs, 1 table, 7 refs

Key Words: Bearings, Journal bearings, Turbines

The purpose of the research is to determine the statistical and dynamical behavior of a large sized lubricated bearing. A testing campaign has been carried out on a full scale bearing of a low pressure turbine in a 320 MW turbo alternator. The results are compared with analytical ones.

81-2582

Experiments on the Dynamic Characteristics of Large Scale Journal Bearings

S. Hisa, T. Matsuura, and T. Someya

Turbine Works, Toshiba Corp., Yokohama, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 223-230, 9 figs, 1 table, 6 refs

Key Words: Bearings, Journal bearings, Stiffness coefficients, Damping coefficients

The dynamic characteristics of large scale journal bearings were studied with special reference to the 20-in. diameter load on pads bearing and 32-in. diameter elliptical bearing. Experiments were carried out in a full scale bearing test rig in which static loads up to 80 tons and dynamic loads between ± 3 and ± 9 tons with the frequency ranging from 20 Hz to 60 Hz can be imposed upon the test bearing. Stiffness and damping coefficients in both laminar and turbulent regime were obtained, and some features of the dynamic characteristics of the two bearings are discussed. It is also suggested that the outlet oil temperature should be used as the representative temperature for the oil film viscosity. Coefficients are applied for the unbalance response analysis of large steam turbogenerator rotors in service.

81-2583

Identification of Stiffness and Damping Coefficients of Journal Bearings by Means of the Impact Method

R. Nordmann and K. Schöllhorn

Technische Hochschule Darmstadt, Fed. Rep. Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK,

Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 231-238, 12 figs, 4 refs

Key Words: Bearings, Journal bearings, Stiffness coefficients, Damping coefficients, Parameter identification techniques, Impact tests

This paper describes an identification method to find system parameters of rotating machines, especially the bearing stiffness and damping coefficients. A rigid rotor, running in journal bearings, is excited by a hammer (pulse testing). Input signals (forces) and output signals (displacements of the rotor) are transformed into the frequency domain and the complex frequency response functions are calculated. Analytical frequency response functions, which depend on the bearing coefficients, are fitted to the measured functions. Stiffness and damping coefficients are the results of an iterative fitting process. Results for a cylindrical bearing are presented and compared with coefficients from other authors.

81-2584

Analytical Nonlinear Bearing Calculations Using a Variational Approach

L.E. Barrett, P.E. Allaire, and D.F. Li

Dept. of Mech. and Aerospace Engrg., Univ. of VA, Charlottesville, VA, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 247-252, 3 figs, 9 refs

Key Words: Bearings, Journal bearings, Variational methods

A solution to the variational equivalent of Reynolds equation for finite length plain cylindrical and segmented journal bearings is presented. An infinite trigonometric series expansion of the pressure field is assumed and the expansion coefficients are found by minimization of the variational principle. The method is intended for use in nonlinear time transient simulations of rotor-bearing systems where finite difference and finite element solutions are computationally too costly to be employed.

81-2585

Estimation of Seal Bearing Stiffness and Damping Parameters from Experimental Data

S.B. Childs, D.W. Childs, and J. Dresden

Texas A&M Univ., College Station, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Church-

ill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 175-180, 4 figs, 1 table, 19 refs

Key Words: Test stands, Measurement techniques, Rotors, Seals, Bearings, Stiffness coefficients, Damping characteristics

A test stand has been constructed to measure displacements and forces related to high performance rotors and their bearings and seals. An existing code for solution of boundary value problems in ordinary differential equations is used to estimate the stiffness and damping parameters for the rotor-bearing-seal. Test results indicate that the test stand and method give a more reliable and economical means of estimating these coefficients than other published means.

GEARS

(Also see Nos. 2656, 2657, 2671, 2676)

81-2586

Vibration Spectra from Gear Drives

A.W. Lees and P.C. Pandey

Scientific Services Dept., Ratcliffe-on-Soar, Nottingham, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 103-108, 4 figs, 3 refs

Key Words: Gear drives, Vibration response spectra

Manufacturing errors are known to have a major influence on the dynamic performance and integrity of gear drives. For example, in large pulverizing mill drive trains, some of the low-speed gears are so heavily loaded that they suffer significant wear quite early in life. Usually there is enough metal in the teeth to give many years' service but profile errors result in increased dynamic gear tooth forces in the worn gears, as well as in the other gears in the drive train. It is important to know the magnitude of these increased forces so that, if necessary, remedial action can be taken to avoid premature failure. The complete shaft/bearing system is analyzed as a set of segments, each segment terminated at a gear mesh. Equations of constraint are then applied which impose on the system an amplitude-controlled vibration (which may be both flexural and torsional). It is shown how this leads to a response which contains frequencies that are orders of shaft speed, as well as frequencies which are independent of shaft speed. Good agreement is observed between vibration spectra taken from operational plant items and spectra predicted theoretically.

COUPLINGS

81-2587

The Selection of Couplings for Engine Test Beds

C.A. Beard

Ricardo Consulting Engineers, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 115-118, 3 figs, 2 refs

Key Words: Couplings, Test facilities, Engines, Combustion engines, Whirling, Torsional response

Problems exist in the selection of couplings for high speed internal combustion engine testbeds. These are reviewed briefly and an approximate, but safe, method for selecting a suitable coupling for particular duties is given. Reference is made to the need to check whirling characteristics as well as the purely torsional aspects. A number of practical installation requirements are referred to briefly.

FASTENERS

81-2588

Vibration Aspects of Rolling Mill Horizontal Drives with Reference to Recent Coupling Development

C. Patterson, J.L. Wearing, and J.D. Fletcher

Dept. of Mech. Engrg., Univ. of Sheffield, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 315-320, 5 figs, 2 tables, 6 refs

Key Words: Joints (junctions), Universal joints, Metal working, Torsional vibration, Translational response, Vibration control

This paper presents a critical survey of the development and increasing industrial use of Hooke (Cardan) joints where high torques are involved. Their use in rolling mill horizontal drives in the metal processing industry is discussed as a specific example and the effects on operating and vibratory behavior identified. The use of these couplings reduces translational and torsional vibratory motion in the mill drives resulting in reduced maintenance, wear and power consumption and improved product quality.

81-2589

Lap Splices in Reinforced Concrete under Impact

T. Rezanoff, J.O. Jirsa, and J.E. Breen

Dept. of Civil Engrg., Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada, ASCE J. Struc. Div., 107 (ST8), pp 1611-1628 (Aug 1981) 9 figs, 4 tables, 10 refs

Key Words: Bonded structures, Joints (junctions), Beams, Concretes, Reinforced concrete, Impact response

The performance of lap splices subjected to impact loading was studied and compared with that of splices under static loading. Nineteen specimens were tested under impact loading, with failure produced in either one impact, in the three to five impacts of incrementally increasing magnitude, or under either unidirectional or reversed cycling of the impact load. Analytical studies were carried out to help evaluate the experimental data. The impact moment capacity of the splices tested was equal to or greater than the static moment capacity.

LINKAGES

81-2590

The Application of Finite Element Methods to the Dynamic Analysis of Flexible Spatial and Co-Planar Linkage Systems

W. Sunada and S. Dubowsky

School of Engrg. and Applied Science, Univ. of California, Los Angeles, CA, J. Mech. Des., Trans. ASME, 103 (3), pp 643-651 (July 1981) 13 figs, 2 tables, 24 refs

Key Words: Linkages, Finite element technique, NASTRAN (computer programs), Component mode synthesis

An analytical method is presented for the dynamics of spatial mechanisms containing complex-shaped, flexible links with application to both high-speed industrial machines and robotic manipulators. Existing NASTRAN-type finite element structural analysis programs are combined with 4 x 4 matrix dynamic analysis techniques and Component Mode Synthesis coordinate reduction to yield a procedure capable of analyzing complex, nonlinear spatial mechanisms with irregularly shaped links in great detail, yet producing a system of equations small enough for efficient numerical integration. The method is applied to two examples.

VALVES

81-2591

Pressure Relief Valve Noise Attenuation

T.R. Bordelon and J.F. Etherington

Dresser Industries, Alexandria, LA, ASME Paper No. 81-PVP-38

Key Words: Valves, Pressure regulators, Noise reduction

Noise sources related to safety relief valve discharge piping systems are identified. A brief discussion of noise terminology is presented in conjunction with a method of estimating the magnitude of noise sources. Methods to reduce noise levels along with silencer selection and installation guidelines are presented.

SEALS

(Also see No. 2585)

81-2592

Labyrinth Seal Effects on Rotor Whirl Instability

B.T. Murphy and J.M. Vance

Dept. of Mech. Engrg., Texas A&M Univ., College Station, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 369-373, 3 figs, 1 table, 6 refs

Key Words: Seals, Rotors, Whirling

The destabilizing effect of labyrinth seals on rotor whirl was first identified by Alford in 1965. Alford's analytical model included the assumption of choked flow at both the inlet and outlet blades of a two blade seal. This paper points to other information which indicates that choked flow can exist only at the exit blade. Under the latter assumption an analysis is performed for a multiblade labyrinth seal. The effects on rotor response and whirl stability are discussed.

81-2593

Flow Induced Spring Constants of Labyrinth Seals

H. Benckert and J. Wachter

Institut fuer Thermische Stroemungsmaschinen, Univ. of Stuttgart, Stuttgart, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill

College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 53-63, 13 figs, 14 refs

Key Words: Rotors, Seals, Compressors, Fluid-induced excitation

Self-excited rotor vibrations which are a function of output are being increasingly observed in high-performance turbomachinery, in particular high-pressure compressors. A possible source of these rotor instabilities lies in the dynamic behavior of the labyrinth seals. Information on flow-induced spring constants in these types of machines is necessary to achieve a more effective vibration analysis. The work presented deals with the force patterns in eccentric-mode labyrinth seals, the exciting lateral force components perpendicular to the rotor displacement plane, and the restoring force components in this plane. The discussion includes the effects of operational parameters such as the differential pressure ratio, speed and entry flow conditions as well as the geometry of the labyrinth on the spring characteristics of these components. Stability calculations for a high-pressure steam turbine and a radial compressor demonstrate the application of the results.

81-2594

Elastohydrodynamic Lubrication of Offset O-Ring Rotary Seal

M.S. Kaisi

Kaisi Engrg., Inc., Houston, TX, J. Lubric. Tech., Trans. ASME, 103 (3), pp 414-427 (July 1981) 27 figs, 21 refs

Key Words: Shafts, Seals, Elastomeric seals, Lubrication, Elastohydrodynamic properties

A fundamental research into the lubrication mechanism and operation of a new type of rotary shaft seal has been conducted. Optical interference technique was successfully used to study the film profiles with optically smooth elastomer seals. Elastohydrodynamic lubrication was found to exist over a wide range of operating conditions. A study of the other performance variables for the Offset-Seal define its useful application range to be between the Packing-Gland and Face-Seal.

81-2595

An Analysis of Mechanical Face Seal Vibrations

I. Etsion and Y. Dan

Dept. of Mech. Engrg., Technion, Haifa, Israel, J.

Lubric. Tech., Trans. ASME, 103 (3), pp 428-435 (July 1981) 4 figs, 21 refs

Key Words: Seals, Rings, Vibration analysis

The motion of a flexibly mounted ring in a mechanical face seal is described in its major three degrees of freedom. The equations of motion include fluid film as well as flexible support forces and moments. These equations are linearized using small perturbation analysis. It is shown that for small perturbation the axial motion is uncoupled with the two angular ones and is always stable. A condition for angular stability is derived relating seal operating conditions to its geometry and other design parameters.

81-2596

Analysis of High Pressure Oil Seals for Optimum Turbocompressor Dynamic Performance

R.G. Kirk and J.C. Nicholas

Turbo Machinery Group, Ingersoll-Rand Co., Phillipsburg, NJ, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 125-131, 10 figs, 3 refs

Key Words: Seals, Turbocompressors, Rotors, Computer-aided techniques, Vibration analysis

The influence of high pressure oil seal rings on the response and stability of turbocompressors is discussed and a method of analysis presented which can be automated for digital computer simulation. The method of analysis is summarized for calculation of the dynamic characteristics including the influence of sealing pressure and thermal equilibrium of the oil film. The results of automated dynamic simulations of turbocompressor systems, including the influence of oil seals, are presented for both steady-state response and dynamic stability. The advantages and disadvantages of the oil seals with regard to vibration performance are discussed for supercritical operation.

STRUCTURAL COMPONENTS

BARS AND RODS

81-2597

Apparent Complex Young's Modulus of a Longitudinally Vibrating Viscoelastic Rod

T. Pritz

Central Research and Design Inst. for Silicate Industry, 1034 Budapest, Becs ut 126/128, Hungary, J. Sound Vib., 77 (1), pp 93-100 (July 8, 1981) 5 figs, 1 table, 19 refs

Key Words: Rods, Viscoelastic properties, Wave propagation, Longitudinal vibration

Longitudinal vibration of a viscoelastic rod with a finite lateral dimension is theoretically analyzed on the basis of the approximate Love theory. The frequency range where the Love theory gives good approximation and its accuracy in that range are determined. The theory predicts that the wave propagation in a viscoelastic rod is not governed solely by the complex Young's modulus of the material at higher frequencies, due to the lateral motion, but by its apparent value. It is shown that the apparent dynamic Young's modulus is smaller and the apparent loss factor is larger than the corresponding actual values for the material. The differences between the apparent and actual values depend on the lateral dimension to wavelength ratio and on the complex elastic constants as well.

BEAMS

(Also see No. 2511)

81-2598

Dynamic Response of a Beam with a Geometric Nonlinearity

S.F. Masri, Y.A. Mariamy, and J.C. Anderson
Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 404-410 (June 1981) 9 figs, 17 refs

Key Words: Beams, Geometric effects, Viscous damping, Harmonic excitation, Random excitation

Analytical and experimental studies were made of the dynamic response of a system with a geometric nonlinearity, which is encountered in many practical engineering applications. An exact solution was derived for the steady-state motion of a viscously damped Bernoulli-Euler beam with an unsymmetric geometric nonlinearity, under the action of harmonic excitation. Experimental measurements of a mechanical model under harmonic as well as random excitation verified the analytical findings. The effect of various dimensionless parameters on the system response was determined.

81-2599

Beam Models for Predicting Dynamic Elastic Response

V.H. Neubert and V.P. Rangaiah
Pennsylvania State Univ., State College, PA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 355-361 (July-Aug 1981) 5 figs, 2 tables, 5 refs

Key Words: Beams, Bernoulli-Euler method, Natural frequencies, Transient response, Lumped parameter method

Further investigation of the three-parameter lumped mass model for the prediction of natural frequencies and transient response of Bernoulli-Euler clamped-clamped beams has resulted in a revised model, which is slightly superior to the original model as it is applicable over a wider frequency range.

81-2600

Static and Dynamic Analyses of Thick Beams of Bimodular Materials

C.W. Bert and A.D. Tran
School of Aerospace, Mech. and Nuclear Engrg., Univ. of Oklahoma, Norman, OK, Rept. No. OU-AMNE-81-7, 68 pp (July 1981) 21 figs, 14 tables, 58 refs

Key Words: Beams, Timoshenko theory, Transient response, Asymmetry, Stiffness

This report deals with the behavior of beams made of bimodular materials, which have one value for the elastic modulus in tension and another in compression. The transfer-matrix approach is used to investigate the small-deflection response to a variety of loadings, both static and transient. The beam is modeled as a Timoshenko beam; i.e., both transverse shear deformation and rotatory inertia are included. Within each field element, provision is made for a neutral-surface position (locus of points having a zero value for the total axial normal strain) that may vary linearly with axial position within the element. The report consists of two distinct parts: Part I covers the static behavior, while Part II deals with transient dynamic behavior.

CYLINDERS

(Also see Nos. 2536, 2629, 2673)

FRAMES AND ARCHES

81-2601

Post-Elastic Dynamics of Three-Dimensional Frames

A.G. Gillies and R. Shepherd

Beca, Carter, Hollings & Ferner, Consulting Engrs., Wellington, New Zealand, ASCE J. Struc. Div., 107 (ST8), pp 1485-1501 (Aug 1981) 10 figs, 1 table, 4 refs

Key Words: Framed structures, Concretes, Reinforced concrete, Seismic design, Earthquake resistant structures

The time-history response of a three-dimensional reinforced concrete frame structure to concurrent earthquake ground motions is analyzed. Yielding is allowed in both beams and columns by a series of yield surface options selected according to the principal structural actions of the component elements. Comparisons between the behavior patterns arising from unidirectional and concurrent earthquake loading indicate that the nonlinear response predicted by a full three-dimensional analysis is significantly different from the response based on a planar frame idealization. Concurrent loading causes asymmetric distribution of yield as a result of the interaction of the orthogonal displacement components, and this gives rise to an eccentricity between the mass and the instantaneous center of stiffness at some levels in the building. Nominally symmetric buildings can develop torsional responses in moderate earthquakes.

PANELS

(Also see No. 2650)

81-2602

Sound Transmission through Elastically Supported Sandwich Panels into a Rectangular Enclosure

S. Narayanan and R.L. Shanbhag
Dept. of Appl. Mechanics, Indian Inst. of Tech., Madras, India, J. Sound Vib., 77 (2), pp 251-270 (July 22, 1981) 5 figs, 3 tables, 14 refs

Key Words: Panels, Sandwich structures, Viscoelastic core-containing media, Enclosures, Sound transmission

Sound transmission through viscoelastic sandwich panels into rectangular enclosures is investigated in the low frequency range (0 - 1000 Hz). Both harmonic and stationary random external pressure fields are considered. Two opposite edges of the plate are simply supported while the other two edges are elastically supported. A forced damped normal mode analysis is used for response calculations. Numerical results are presented for different parameters of the viscoelastic core.

PLATES

81-2603

Elastic Instability of a Heated Annular Plate under Lateral Pressure

J. Tani

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 399-403 (June 1981) 7 figs, 16 refs

Key Words: Plates, Annular plates, Thermal excitation

On the basis of the dynamic version of the nonlinear von Kármán equations, a theoretical analysis is performed on the elastic instability of a uniformly heated, thin, annular plate which has suffered a finite axisymmetric deformation due to lateral pressure. The linear free vibration problems around the finite axisymmetric deformation of the plate are solved by a finite-difference method. By examining the frequency spectrum with various asymmetric modes, the critical temperature rise under which the axisymmetric deformation becomes unstable due to the bifurcation buckling is determined, which is found to jump up to 7.2 times within a range of very small lateral pressure.

81-2604

Vibration of Thick Rectangular Plates of Bimodulus Composite Material

C.W. Bert, J.N. Reddy, W.C. Chao, and V.S. Reddy
School of Aerospace, Mech. and Nuclear Engrg., The Univ. of Oklahoma, Norman, OK, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 371-376 (June 1981) 6 tables, 20 refs

Key Words: Plates, Rectangular plates, Finite element technique, Small amplitudes

A finite-element analysis is carried out for small-amplitude free vibration of laminated, anisotropic, rectangular plates having arbitrary boundary conditions, finite thickness shear moduli, rotatory inertia, and bimodulus action (different elastic properties depending upon whether the fiber-direction strain is tensile or compressive). The element has five degrees of freedom, three displacements and two slope functions, per node. An exact closed-form solution is also presented for the special case of freely supported single-layer orthotropic and two-layer, cross-ply plates. This solution provides a benchmark to evaluate the validity of the finite-element analysis. Both solutions are compared with numerical results existing in the literature for special cases (all for ordinary, not bimodulus, materials), and good agreement is obtained.

81-2605

Nonlinear Theory for Flexural Motions of Thin Elastic Plate, Part 1: Higher-Order Theory

N. Sugimoto

Dept. of Mech. Engrg., Faculty of Engrg. Science,
Osaka Univ., Toyonaka, Osaka, Japan, J. Appl.
Mechanics, Trans. ASME, 48 (2), pp 377-382 (June
1981) 21 refs

Key Words: Plates, Flexural vibration

This paper develops a comprehensive higher-order theory for flexural motions of a thin elastic plate, in which the effect of finite thickness of the plate and that of small but finite deformation are taken into account. Based on the theory of nonlinear elasticity for a homogeneous and isotropic solid, the nonlinear equations for the flexural motions coupled with the extensional motions are systematically derived by the moment asymptotic expansion method. Denoting by ϵ the ratio of the thickness of the plate to a characteristic wavelength of flexural motions, an order of characteristic deflection is assumed to be ϵ^2 and that of a characteristic strain ϵ^3 . The displacement and stress components are sought consistently up to the next higher-order terms than those in the classical theory.

81-2606

Nonlinear Theory for Flexural Motions of Thin Elastic Plate, Part 2: Boundary-Layer Theory Near the Edge

N. Sugimoto

Dept. of Mech. Engrg., Faculty of Engrg. Science,
Osaka Univ., Toyonaka, Osaka, Japan, J. Appl.
Mechanics, Trans. ASME, 48 (2), pp 383-390 (June
1981) 13 refs

Key Words: Plates, Flexural vibration, Elastic properties, Boundary layer excitation

This paper deals with, as a continuation of Part 1 of this series, the boundary-layer theory for flexural motions of a thin elastic plate. In the framework of the higher-order theory developed in Part 1, three independent boundary conditions at the edge of the plate are too many to be imposed on the essentially fourth order differential equations. To overcome this difficulty, a boundary layer appearing in a narrow region adjacent to the edge is introduced. Using the matched asymptotic expansion method, uniformly valid solutions for a full plate problem are sought. The boundary-layer problem consists of the torsion problem and the plane problem. Three types of the edge conditions are treated, the built-in edge, the free edge, and the hinged edge. Depending on the type of edge condition, the nature of the boundary layer is characterized. After solving the boundary-layer problem, "reduced" boundary conditions relevant to the higher-order theory are established.

SHELLS

(Also see No. 2673)

81-2607

Dynamic Stability of Truncated Conical Shells under Pulsating Torsion

J. Tani

Inst. of High Speed Mechanics, Tohoku Univ., Sendai,
Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp
391-398 (June 1981) 7 figs, 1 table, 13 refs

Key Words: Shells, Conical shells, Torsional excitation, Periodic excitation

The dynamic stability of clamped, truncated conical shells under periodic torsion is analyzed by the Galerkin method in conjunction with Hsu's results. The instability regions of practical importance are clarified for relatively low frequency ranges. Numerical results indicate that under the purely periodic torsion only the combination instability region exists but that with an increase in the static torsion the principal instability region becomes most significant. The relative openness of the instability regions is found to depend sensitively on the circumferential phase difference of two vibration modes excited simultaneously at the resonance with the same circumferential wave number.

81-2608

Vibrations of Cylindrical Shells with Time-Dependent Boundary Conditions

S.Y. Lu

Univ. of Florida, Gainesville, FL, ASME Paper No.
81-PVP-21

Key Words: Shells, Cylindrical shells, Time-dependent parameters, Boundary condition effects

Dynamic edge effects on the vibrations of elastic shells are studied by separation of variables. The linear nonhomogeneous differential equations are satisfied by separating the displacement functions into two parts: a free vibration solution and a particular solution which satisfies the time-dependent boundary conditions. The theory is applied to the solution of the clamped-clamped cylinder with oscillating edges.

81-2609

The Effects of Wall Discontinuities on the Propagation of Flexural Waves in Cylindrical Shells

C.R. Fuller

Inst. Sound Vib. Res., Southampton Univ., UK,
Rept. No. ISVR-TR-106, 64 pp (Mar 1980)
PB81-168858

Key Words: Shells, Cylindrical shells, Pipes (tubes), Vibration isolation, Discontinuity-containing media, Flexural waves

The transmission of flexural type waves through various discontinuities in the walls of cylindrical shells is investigated. Theoretical curves of transmission loss are obtained for different circumferential wavenumbers and wave types, as functions of frequency. Material stiffness and extensional phase speed, together with the relationship between radial vibration amplitude and total wave power of propagation, are important factors which are found to strongly influence wave transmission through discontinuities. Some practical results useful for predicting the performance of typical pipe isolators (in vacuo) are obtained.

81-2610

Wave Propagation in a Thin-Walled Viscoelastic Tube Due to Sudden Release of External Loading

T.B. Moodie, J.B. Haddow, and R.J. Tait

Dept. of Mathematics, Univ. of Alberta, Edmonton, Alberta, Canada, Intl. J. Engrg. Sci., 19 (11), pp 1441-1448 (1981) 2 figs, 4 refs

Key Words: Shells, Cylindrical shells, Tubes, Viscoelastic properties

An approximate thin shell theory is used to analyze the dynamic response of an axially constrained incompressible viscoelastic cylindrical tube, due to the sudden release of an axially symmetric uniformly distributed line loading. It is assumed that the tube is sufficiently long that end effects can be neglected. The analysis is based on the linear theory of viscoelasticity and a standard viscoelastic material is considered. Numerical results are obtained by the Fast Fourier Transform algorithm and are presented graphically for a wide range of parameter values.

81-2611

Damage Characteristics of an Infinite Cylindrical Shell Excited by a Transient Acoustic Wave

T.L. Geers and C.L. Yen

Palo Alto Res. Lab., Lockheed Missiles and Space Co., Inc., Palo Alto, CA, Rept. No. LMSC-D686495, 29 pp (Mar 1981)
AD-A096 686

Key Words: Shells, Cylindrical shells, Submerged structures, Transient response, Sound waves, Interaction: structure-fluid

An analytical/computational technique previously developed for determining the geometrically and constitutively nonlinear response of a submerged, infinite cylindrical shell to a transverse, transient acoustic wave is used to study the damage behavior of the shell. Incident waves of rectangular pressure-profile are considered, nonlinear transient response computations are performed, and damage results are described in terms of iso-damage curves based on extensional set strain. Results generated through the use of the doubly asymptotic approximation for treatment of the fluid-structure interaction differ appreciably from their exact counterparts.

81-2612

Modal Response of Circular Cylindrical Shells with Structural Damping

A.W. Leissa and K.M. Iyer

Dept. of Engrg. Mechanics, Ohio State Univ., Columbus, OH, J. Sound Vib., 77 (1), pp 1-10 (July 8, 1981) 4 figs, 7 tables, 12 refs

Key Words: Shells, Circular shells, Cylindrical shells, Periodic excitation, Damping effects, Hysteretic damping, Modal analysis

Although a vast literature exists dealing with the free vibration of circular cylindrical shells, relatively little can be found for the problem of dynamic response due to sinusoidally varying exciting forces, especially when damping exists. In the present work the response of a shell subjected to a sinusoidal radial pressure is studied, when the pressure has the same distribution as the normal mode shape. Structural (hysteresis) damping is considered. For a unit amplitude of exciting pressure, the lowest frequency modes are found to yield the largest resonant response. Because of a small amount of mode coupling, the peak amplitudes are found to be not quite inversely proportional to the strength of the damping, and there is a slight shift in the locations of the resonant peaks.

81-2613

The Effect of Viscosity on Free Vibrations of Submerged Fluid-Filled Spherical Shells

T.C. Su

Dept. of Civil Engrg., Texas A&M Univ., College Station, TX, J. Sound Vib., 77 (1), pp 101-125 (July 8, 1981) 13 figs, 16 refs

Key Words: Shells, Spherical shells, Submerged structures, Fluid-induced excitation, Fluid-filled containers, Viscosity effects

In order to clarify the effect of fluid viscosity on the vibration of submerged elastic shells, the axisymmetric free oscillations of a fluid-filled spherical shell immersed in a sound field are studied. The dynamic response of the shell is determined by the classical normal mode method, while a boundary layer approximation is employed for the fluid medium. In the absence of viscosity, the shell motion is always damped due to the compressibility of the fluid outside the shell. It is shown that, except for the appearance of natural frequencies with a large damping component, the presence of surrounding fluid outside a fluid-filled shell produces only small changes in the real part of the frequency spectra. The analysis of the influence of viscosity reveals that the viscosity has essentially no effect on the frequencies of shells of moderate thickness. However, the viscous damping is predominant for the non-radiating modes of a fluid-filled submerged shell and the damping is due solely to viscosity for all modes if the outer fluid is assumed incompressible.

PIPES AND TUBES

81-2614

Comparison of LMFBR Piping Response Obtained Using Response Spectra and Time History Methods

G. Hulbert

Westinghouse Advanced Reactors Div., Madison, PA, ASME Paper No. 81-PVP-28

Key Words: Piping systems, Seismic response, Spectrum analysis

The dynamic response to a seismic event is calculated for a piping system using a response spectrum analysis method and two time history analysis methods. The results from the analytical methods are compared to identify causes for the differences between the sets of analytical results. Comparative methods are also presented which help to gain confidence in the accuracy of the analytical methods in predicting piping system structural response during seismic events.

81-2615

The Use of the Split Ring in Modeling Ductile Axial Crack Extension in Pipes

A. Emery, M. Perl, A. Kobayashi, and W. Love

Dept. of Mech. Engrg., Univ. of Washington, Seattle, WA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 151-154 (May 1981) 6 figs, 16 refs

Key Words: Pipes (tubes), Crack propagation

An earlier described ring model for the calculation of axial crack propagation in pipes is investigated numerically. The model assumes that the pipe may be divided into a series of rings. Those rings behind the crack are split and those ahead are whole. By calculating the time history of the opening of the ring behind the crack tip and relating this opening displacement to a fracture criterion, the history of the crack tip extension may be computed.

81-2616

A Sensitivity Study on Numerical Analysis of Dynamic Girth Crack Propagation

A.S. Kobayashi, A.F. Emery, W.J. Love, and A. Jain
Dept. of Mech. Engrg., Univ. of Washington, Seattle, WA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 169-174 (May 1981) 9 figs, 1 table, 20 refs

Key Words: Pipes (tubes), Crack propagation

Dynamic motion of pre-existing girth crack in an axially stressed, 18-in-diameter 316 stainless steel pipe in the presence of large-scale yielding was analyzed by a finite difference shell code. A critical crack tip opening angle (CTOA) was used as a dynamic fracture criterion and the sensitivities of dynamic crack propagation to differences in CTOA, finite differences mesh sizes, initial crack sizes and initial crack bluntnesses, were analyzed numerically. Hold-off times for the onset of dynamic crack propagation nearly doubled and tripled, while terminal crack velocities decreased about 22 percent and 47 percent when the CTOA was increased from 0.10 to 0.19 and to 0.30, respectively. Doubling of the axial length of the initial crack length and an overdriving condition simulated by a larger CTOA did not change the terminal crack velocity.

81-2617

Fluid Elastic Vibration of Tube Array in Cross Flow

H. Tanaka and S. Takahara

Aero-Hydraulics Res. Lab., Nagasaki Technical Inst., Mitsubishi Heavy Industries Ltd., Nagasaki, Japan, J. Sound Vib., 77 (1), pp 19-37 (July 8, 1981) 17 figs, 2 tables, 10 refs

Key Words: Heat exchangers, Tube arrays, Fluid-induced excitation

It is well-known that a cylinder bundle vibrates in a cross flow. Studies of the vibration have been made and it has been established that the vibration is a fluid elastic vibration. However, this theory, which is based on quasi-static fluid forces, does not always hold good for all vibration phenomena. In the theory used in this paper unsteady fluid dynamic forces are considered, which are induced by the vibrating cylinders. Since theoretical prediction of unsteady fluid dynamic forces is difficult, model tests were conducted to measure the fluid forces. The equations of motion of the cylinders were deduced and critical velocities were calculated by using the measured unsteady fluid dynamic forces. Critical velocity tests were also conducted with cylinders supported by elastic spars. The calculated critical velocities coincided well with the test results. Effects of fluid density on the critical velocity were studied and it was found that the critical velocity in a low density fluid like air is proportional to the one half power of the mass damping parameter, as predicted by the previous theory. However, the critical velocity in a high density fluid is less influenced by the mass damping parameter. The effects of detuning of the natural frequency on the critical velocity were also considered.

81-2618

Ductile Fracture of Pipes and Cylindrical Containers with a Circumferential Flaw

F. Erdogan and F. Delale

Dept. of Mech. Engrg. and Mechanics, Lehigh Univ., Bethlehem, PA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 160-168 (May 1981) 14 figs, 1 table, 20 refs

Key Words: Pipes (tubes), Fatigue life, Crack propagation, Shells

The paper deals with the problem of ductile fracture of a pipe or cylindrical container having a relatively long and deep circumferential part-through crack or a through crack and subjected to a uniform axial membrane load in the crack region. After describing the evolution of the ductile fracture process, first the results of the elasticity solution for the circumferentially cracked cylindrical shell based on the Reissner's transverse shear theory are presented. The elastic-plastic part-through crack problem is then considered. In the analysis the plastic deformations are approximated by a perfectly plastic layer similar to the conventional Dugdale model. The load carrying capacity of the cylinder is then estimated in various ways by using the crack opening stretch along the leading edge of the crack as the critical load factor.

81-2619

Continuum Solution of Simulated Pipe Whip Problem

M. Lashkari and V.I. Weingarten

Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, ASCE J. Struc. Div., 107 (ST8), pp 1443-1463 (Aug 1981) 25 figs, 1 table, 8 refs

Key Words: Pipe whip, Nuclear power plants, Piping systems

The pipe whip problem is a highly nonlinear problem which, except for special conditions, is usually solved numerically. When a dynamic load is applied to the base of a pipe (striker) whose end impacts another pipe (target), it is possible for both the striker and the target to experience plastic deformations during impact. A finite element solution considering the nonlinear impact problem with material nonlinearity has been carried out. At the point when the material becomes plastic, high frequency oscillations can set up in the continuum model. Experimental data indicate that these oscillations quickly disappear due to material damping. The effects of plasticity are considered, as are Rayleigh damping and nonlinear damping in the target material.

DUCTS

(Also see No. 2563)

81-2620

Flow-Acoustic Coupling in Ducts

P.O.A.L. Davies

Inst. Sound Vib. Res., Univ. of Southampton, Southampton, UK, J. Sound Vib., 77 (2), pp 191-209 (July 22, 1981) 10 figs, 2 tables, 22 refs

Key Words: Ducts, Discontinuity-containing media, Sound generation

Experimental data for two mechanisms of sound generation at area discontinuities in flow ducts are described and discussed. The first step in the process is the development of an ordered train of vortices in the shear layer produced by a separating flow. Though not themselves strong radiators of sound, such vortices can excite resonators strongly. The acoustic field of the resonator provides the sound waves which synchronize the vortex motion, producing a self-sustaining oscillation. Alternatively, synchronization of the vortex motion with an incident acoustic field from a source upstream can enhance the sound by transferring energy from the mean flow.

BUILDING COMPONENTS

81-2621

Effective Width of Floor Systems for Application in Seismic Analysis

F.S. Cotran and W.J. Hall

Dept. of Civil Engrg., Univ. of Illinois at Urbana-Champaign, Rept. No. STRUCTURAL RESEARCH SER-486, UILU-ENG-80-2021, NSF/RA-800428, 96 pp (Nov 1980)
PB81-168296

Key Words: Frames, Floors, Steel, Concretes, Seismic excitation

Effective width coefficients for floor systems have been developed for use in the analysis of frames subjected to lateral seismic loads. The method described covers a wide range of practical values of the slab dimensions and can be applied to both steel and concrete frames and to cases of flat slabs as well as slabs with supporting beams. The investigation is based on a parametric study of typical interior panels of floor systems, with and without supporting beams, using elastic finite element analysis to model the behavior of the floor system when the frame is subjected to lateral loads. The theoretical derivation of the method and the procedure employed for the finite element analysis is covered. Results of the study and a proposed simplified method of analysis for estimating the composite properties are presented. Simple examples illustrate application of the method, emphasizing seismic analysis and the resistance of floor systems under dynamic loads.

ELECTRIC COMPONENTS

GENERATORS

(See No. 2525)

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see Nos. 2545, 2546, 2547, 2548, 2650)

81-2622

A Comparison of Community Response to Aircraft Noise at Toronto International and Oshawa Municipal Airports

S.M. Taylor, F.L. Hall, and S.E. Birnie

Dept. of Geography, McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., 77 (2), pp 233-244 (July 22, 1981) 2 figs, 4 tables, 15 refs

Key Words: Airports, Traffic noise, Aircraft noise, Human response

Debate continues over the validity of a single dose-response relationship to describe annoyance due to transportation noise. Doubts about the appropriateness of a single relationship have centered primarily on the issue of differential response to the same noise level for different sources; e.g., aircraft, road traffic and trains. However, recent work suggests that response may vary for different types of the same source, namely aircraft, dependent upon the character, and specifically the number, of operations. Recent data collected around Toronto International and Oshawa Municipal airports permit a test of differences in four aggregate response variables. For the same NEF level, the percent at all annoyed at the two airports is not statistically different. The percent highly annoyed and the percent reporting speech interference are both significantly greater at Toronto but the percent reporting sleep interruption is greater at Oshawa. These differences can be explained in terms of the operational characteristics of the two airports.

81-2623

Industrial Noise Pollution - Part 2: Identifying and Controlling Industrial Noise Sources

R.L. Bannister

Steam Turbine-Generator Div., Westinghouse Electric Corp., Lester, PA, Mech. Engrg., 103 (8), pp 24-29 (Aug 1981) 5 figs, 30 refs

Key Words: Noise generation, Industrial facilities

It has been reported that the original proposed OSHA workplace noise standards of 85 dB would have cost industry between \$18 billion and \$31 billion (in 1976 dollars) to meet. The compromise standards that OSHA has now worked out will allow 90 dB but will still cost industry about \$250 million. To comply with these newly established requirements, industry will have to examine everything from the design of its products to its manufacturing processes. The causes of excessive noise will have to be determined and effective and economical solutions will then have to be employed either to reduce the noise to acceptable levels or to shield the worker from its damaging impact.

81-2624

Materials for Noise and Vibration Control

W.E. Purcell

S/V, Sound and Vibration, 15 (7), pp 4-30 (July 1981)

Key Words: Materials, Noise reduction, Vibration control, Acoustic absorption, Noise barriers, Vibration damping, Vibration isolation

A comprehensive mini-handbook for the selection and application of commonly available noise and vibration control materials. Basic information is provided on the characteristics of sound absorptive, sound barrier, vibration damping, and vibration isolation materials.

81-2625

Investigation of a Parametric Acoustic Receiving Array for Mobile Applications

C.R. Clubertson, R.A. Lamb, and D.F. Rohde

Applied Res. Labs., Univ. of Texas at Austin, Austin, TX, Rept. No. ARL-TR-80-53, 40 pp (Nov 5, 1980) AD-A096 563

Key Words: Acoustic arrays, Parameter excitation, Under-water sound

The parametric acoustic receiving array (PARRAY) exploits the nonlinearity of acoustic waves in water to achieve directional reception of low frequency acoustic waves using only two high frequency transducers and associated electronics. In mobile applications the parametric receiver will be required to operate under the influence of sensor motion, and in water that is sometimes turbulent. This report describes these two areas of technical risk which are pertinent to the successful implementation of PARRAYs on submarine platforms. Analysis, fabrication, and testing of a phase-locked loop receiver is described.

SHOCK EXCITATION

81-2626

A Note on Velocity Inversion of Diffracted Waves

J.K. Cohen and N. Bleistein

Math. and Computer Science Dept., Univ. of Denver,

Denver, CO 80208, Wave Motion, 3 (3), pp 279-282 (July 1981) 4 figs, 12 refs

Key Words: Wave propagation

In a recent article, the authors developed and solved an integral equation for determining small variations in propagation speed. Since the field data is high frequency data on the geophysical scale, it is important to verify that the inversion scheme correctly produces phenomena associated with high frequency data. The inversion results obtained for the case of a data set containing an edge and for the case of a data containing a buried focus are presented.

81-2627

Earthquake Research for the Safer Siting of Critical Facilities

J.L. Cluff

Natl. Academy of Sciences, Washington, DC, 59 pp (1980)

DOE/CH/93003-4

Key Words: Life line systems, Earthquake damage

The task of providing the necessities for living, such as adequate electrical power, water, and fuel, is becoming more complicated with time. Some of the facilities that provide these necessities would present potential hazards to the population if serious damage were to occur to them during earthquakes. Other facilities must remain operable immediately after an earthquake to provide life-support services to people who have been affected. The purpose of this report is to recommend research that will improve the information available to those who must decide where to site these critical facilities, and thereby mitigate the effects of the earthquake hazard.

81-2628

Effect of Earth Media on the Seismic Motion of Embedded Rigid Structures

J.J. Fedock and H.L. Schreyer

Dept. of Civil Engrg., Univ. of Santa Clara, Santa Clara, CA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 311-327 (July-Aug 1981) 11 figs, 1 table, 26 refs

Key Words: Interaction: soil-structure, Seismic waves, Seismic response

A finite element analysis is performed to determine the influence of the choice of a constitutive model for the earth medium upon the response to seismic waves of an embedded rigid structure. The seismic forcing function is characterized by Rayleigh waves with amplitude parameters adjusted to provide identical free-field motion at a surface reference point for one particular sand represented with elastic, plastic and viscoelastic models. Within the limitations of the analysis, the result is that the steady-state rigid body motions of the embedded structure are essentially identical for these constitutive relations and, consequently, it is appropriate to use an elastic representation for the earth medium.

81-2629

Dynamic Crack Propagation in Precracked Cylindrical Vessels Subjected to Shock Loading

C.H. Popelar, P.C. Gehlen, and M.F. Kanninen
Dept. of Engrg. Mechanics, The Ohio State Univ.,
Columbus, OH, J. Pressure Vessel Tech., Trans.
ASME, 103 (2), pp 155-159 (May 1981) 3 figs,
1 table, 4 refs

Key Words: Cylinders, Crack propagation, Ships, Blast response

Previous work has shown that a speed-independent dynamic fracture toughness property can be used in an elastodynamic analysis to describe crack initiation and unstable propagation under impact loading. In this paper, a further step is taken by extending the analysis from simple laboratory test specimens to treat more realistic crack-structure geometries. A circular cylinder with an initial part-through wall crack subjected to an impulsive loading on its inner surface is considered. The crack is in a radial-axial plane and has its length in the axial direction long enough that a state of plane strain exists at the center of the crack. Crack growth initiation and propagation through the wall is then calculated. It is found that, once initiated, crack propagation will continue until the crack penetrates the wall. Crack arrest within the wall does not appear to be possible under the conditions considered in this paper.

VIBRATION EXCITATION

(Also see No. 2624)

81-2630

The Description of Random Vibration

J.D. Robson

Mech. Engrg. Dept., Univ. of Glasgow, UK, Intl. J. Vehicle Des., 2 (3), pp 255-275 (1981) 7 figs

Key Words: Random vibration, Structural response, Probability density function

This paper considers the whole problem of the description of random processes, with the two objects of revealing the requirements of description in their most general form and indicating in their proper context the simplifications of Gaussianity and stationarity which give rise to the most commonly used results in random vibration analysis. Single-variate processes are considered first, the additional complications of two-variate processes are then treated, and the general n-variate problem is covered.

81-2631

An Elementary Investigation of Local Vibration

R.E.D. Bishop and S. Mahalingam
Dept. of Mech. Engrg., Univ. College London, UK,
J. Sound Vib., 77 (2), pp 149-163 (July 22, 1981)
8 figs, 3 refs

Key Words: Harmonic excitation

It is well known that, if a system is subjected to harmonic forced excitation, the response may be resonant only in some localized part of the system. One may refer to a resonant "subsystem" which may, or may not, be "small." The familiar reed vibrometer exemplifies a small resonant subsystem while a tuned absorber is a resonant subsystem that is not small. The implications of this are explored for the particular case of a subsystem that is linked to the remainder of the vibrating system at a single generalized co-ordinate.

MECHANICAL PROPERTIES

DAMPING

(Also see Nos. 2532 and 2565)

81-2632

An Attractive Method for Displaying Material Damping Data

D.I.G. Jones

Air Force Wright Aeronautical Labs., Wright Patterson AFB, OH, J. Aircraft, **18** (8), pp 644-649 (Aug 1981) 13 figs, 17 refs

Key Words: Damping coefficients, Damping materials, Data presentation, Nomographs

This paper describes the development of a new reduced-temperature nomogram which greatly facilitates the display and correlation of complex modulus data for a linear thermorheologically simple viscoelastic damping material in such a way that the effects of frequency and temperature can be simultaneously taken into account. The method is based on the well-known temperature-frequency equivalence principle, which allows one to modify the frequency by a factor depending on temperature alone in such a way that complex modulus data points at a given frequency and temperature can be combined into a single set of curves, representing the loss factor and modulus as a function of a single variable, known as the reduced frequency. The superimposition of temperature isotherms completes the nomogram and thereby greatly expands the usefulness of the reduced-frequency graphs by allowing display on a single graph of complex modulus data at any frequency and temperature. This allows the possibility of generating and transmitting engineering data on viscoelastic material behavior to be used in many areas where such materials are being considered for vibration control.

81-2633

Dynamic Pressure Determinations in a Squeeze-Film Damper

R. Holmes and M. Dede

School of Engrg. and Appl. Sciences, Univ. of Sussex, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 71-75, 4 figs, 8 refs

Key Words: Dampers, Squeeze film dampers, Rotors

A comparison of predicted and measured pressures in a squeeze-film damper under dynamic loading is presented. The relation between these pressures and vibration orbits resulting from rotor unbalance is elucidated.

81-2634

Theoretical and Experimental Investigation into the Effectiveness of Squeeze-Film Damper Bearings without a Centralizing Spring

R.A. Cookson and S.S. Kossa

Applied Mechanics Group, Cranfield Inst. of Tech., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 359-366, 7 figs, 1 table, 10 refs

Key Words: Dampers, Squeeze film dampers, Bearings, Turbomachinery

An analytical technique has been developed for determining the effectiveness of squeeze-film damper bearings which do not have a centralizing spring. Squeeze-film damper bearings supporting both rigid and flexible rotors have been analyzed and their performance expressed in terms of non-dimensional system parameters. This analysis has indicated certain clearly defined regions, within the framework of these system parameters, in which the designer should work if he is to produce an effective vibration inhibiting device. An experimental investigation has confirmed that the squeeze-film damper bearing without a centralizing spring can be a very effective method of reducing some forms of vibration in turbomachines.

FATIGUE

(Also see No. 2519)

81-2635

Presentation of Failure Analysis Data by the Fatigue Fracture Mechanics Diagram

R.H. Sailors

American Magotteux Corp., Pulaski, TN, ASME Paper No. 81-PVP-11

Key Words: Crack propagation, Fatigue life, Graphic methods

The integrated crack growth rate equation is presented in graphical form as cyclic stress range versus initial flaw size for various constant cyclic lines. The upper bound of the graph is described by single cycle fracture and lower bound is described by an "engineering defined" threshold value of stress intensity. In many instances the fatigue fracture mechanics diagram simplifies presentation of failure analysis data. It also can illustrate the cause of failure whether it be single or multicycle, and indicate corrective measures needed to avoid repetition of the failure.

81-2636

Dynamic Fracture Initiation in Metals and Preliminary Results on the Method of Caustics for Crack Propagation Measurements

L.B. Freund, J. Duffy, and A.J. Rosakis

Brown Univ., Providence, RI, ASME Paper No. 81-PVP-15

Key Words: Fatigue life, Crack propagation, Metals

Progress is described in the use of an experimental method for studying fracture initiation under dynamic loading conditions in metals. The instrumentation provides unambiguous records of instantaneous average stress on the unfractured ligament and of instantaneous crack opening displacement.

81-2637

An Analysis of, and Some Observations on, Dynamic Fracture in an Impact Test Specimen

T. Nishioka, M. Peri, and S.N. Atluri
Georgia Inst. of Tech., Atlanta, GA, ASME Paper No. 81-PVP-18

Key Words: Fatigue life, Crack propagation, Steel

Numerical simulations of crack-propagation histories in four cases of dynamic tear test experiments on 4340 steel are performed. The influence of the loss of contact of the specimen at various times with either the supports or the tup or both is critically examined. In each case, the variation of the dynamic K-factor for the simulated crack-propagation history is directly computed.

81-2638

Evaluation of Dynamic Load Combination Fatigue Damage

Z.N. Ibrahim and S.A. Gabraiel
Sargent & Lundy Engineers, Chicago, IL, ASME Paper No. 81-PVP-20

Key Words: Fatigue life, Root mean squares

The results of the basic and parametric analyses presented in the preceding sections support the engineering practice of adopting the common cycle elimination technique to evaluate the fatigue damage of the combined, uncorrelated, simultaneous occurrences. This includes employing the square root of sum of squares of the maximum response amplitude and/or range of each of these occurrences, throughout the execution of the cycle elimination process.

81-2639

Fatigue Design in Mining Size Reduction Equipment

V. Svalbonas
Koppers Co., Inc., York, PA, ASME Paper No. 81-PVP-9

Key Words: Mines (excavations), Equipment, Fatigue life

The mining size reduction equipment industry is reviewed regarding efforts to obtain a consistent fatigue design philosophy. Serious structural failures, which have prompted various company efforts in this area, are reviewed. Basic fatigue data are being gathered with the goal of providing consistent design, fabrication and nondestructive examination programs.

81-2640

Parameters and Micromechanisms of Fatigue Crack Growth in Sheet Magnesium Alloy Samples

N.M. Grinberg and V.A. Serdyuk
Physico-Technical Inst. of Low Temperatures, Ukrainian Academy of Sciences, Lenin's Prospect, Kharkov, USSR, Intl. J. Fatigue, 3 (3), pp 143-148 (July 1981) 2 figs, 2 tables, 26 refs

Key Words: Fatigue life, Crack propagation

Growth rates of part-through and through fatigue cracks have been measured for two magnesium alloys - MA12 and IMV6 - and the micromechanisms of fatigue fracture were studied at all stages of growth. Conclusions about the peculiarities of the kinetics and micromechanisms of part-through and through crack growth, depending on the applied stress amplitudes and alloy structure, are made from a comparison of the results obtained.

81-2641

Tests to Determine the Fatigue Strength of Steel Castings Containing Shrinkage

L.P. Pook, A.F. Greenan, M.S. Found, and W.J. Jackson
Natl. Engrg. Lab., East Kilbride, Glasgow, UK, Intl. J. Fatigue, 3 (3), pp 149-156 (July 1981) 12 figs, 5 tables, 18 refs

Key Words: Fatigue tests, Steel

Fatigue tests were carried out on low strength steel castings containing deliberately introduced shrinkage defects. Failure

in most tests originated at defects which could be identified on radiographs, but on the basis of the radiographs, it would not have been possible to predict either the site of the failure or the fatigue strength of the individual specimens. Even gross center-line defects had little effect on the fatigue strength of specimens tested in four point bending, although substantially decreasing the strength of specimen tested in tension. A fracture mechanics analysis was attempted but was not satisfactory due to the difficulty in estimating the stress intensity factors for the irregular flaws concerned and because of excessive yielding in many specimens.

81-2642

Growth of Surface Fatigue Cracks in a Steel Plate

O. Vosikovskiy and A. Rivard

Physical Metallurgy Res. Labs., Ottawa, Ontario, Canada, Intl. J. Fatigue, 3 (3), pp 111-115 (July 1981) 8 figs, 1 table, 11 refs

Key Words: Fatigue (materials), Crack propagation, Steel, Pipelines

The growth rates of surface fatigue cracks, both on the surface and within the plate, have been measured on an X65 pipeline steel plate. To calculate stress intensity ranges the finite-element solution by Raju and Newman has been used. The resulting fatigue crack growth rates are in good agreement with those measured on single-edge notched specimens. The variation in shape of a growing surface fatigue crack is analyzed and compared with other published measurements and analytical predictions by Nair.

81-2643

Probability of Fatigue Failure as a Statistic

A. Tsurui

Engrg. Dept., Kyoto Univ., Kyoto, Japan, Intl. J. Fatigue, 3 (3), pp 125-127 (July 1981) 7 refs

Key Words: Fatigue life, Random excitation, Statistical analysis

The probability of failure is treated as a statistic from the viewpoint that the probability can be determined only through experimental data. On the basis of a statistical theory for large samples, an asymptotic distribution function for the probability of fatigue failure under stationary random external loading is given and a simple policy for fatigue-proof design is proposed.

81-2644

Stress Intensity Factors for Fatigue Cracking of Round Bars

A.S. Salah el din and J.M. Lovegrove

Civil Engrg. Dept., Southampton Univ., Southampton, UK, Intl. J. Fatigue, 3 (3), pp 117-123 (July 1981) 11 figs, 2 tables, 18 refs

Key Words: Fatigue life, Bars

The stress intensity factor for a single edge crack of either straight or circular front in a round bar has been determined using both the degenerated quarter-point isoparametric finite element and experimental fatigue crack growth data, and compared with values found by earlier investigators. The results of this study confirm that the stress intensity factors for straight edged surface cracks are lower in round bars than in square bars and a comparison of finite element and experimental results indicates that the effective stress intensity factor at the centre of the fatigue crack front in a round bar is 17% greater than its theoretical value. A correction function is proposed to account for the effect on the stress intensity factor of the circular boundary of a round bar.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

81-2645

A New Way to Capture Elusive Signals

C. Somers

Biomation Div., Gould Inc., Santa Clara, CA, Mach. Des., 53 (10), pp 111-115 (May 7, 1981)

Key Words: Wave analyzers, Measuring instruments

Recently developed devices for capturing high-speed transient signals, the waveform recorders, are described. They are used in applications requiring high speed monitoring of multiple sensors. Monitoring of stress and strain data from high-rate dynamic tests is a typical example.

81-2646

A Matched Impedance, Electrostatic Approach to Hydrophone Design

J.A. Clark

Acousto-Optics Lab., Catholic Univ. of America, Washington, DC, J. Sound Vib., 77 (1), pp 51-59 (July 8, 1981) 4 figs, 15 refs

Key Words: Hydrophones, Sound transducers, Design techniques

A new type of acoustically transparent capacitor hydrophone is described and demonstrated. The hydrophone is built with a dielectric material between the capacitor plates which is similar in acoustic impedance to that of water. A theoretical model of this matched impedance type of capacitor hydrophone is developed and compared with a theory of air-filled capacitor hydrophones. Unlike the earlier air-filled types of capacitor hydrophones, the sensitivity is found to be independent of frequency and of parameters determining the capacitance of the hydrophone. Amplitude transmission ratios greater than 96% demonstrate the acoustical transparency of the device.

81-2647
Combining Holography with Speckling for Vibration Analysis

J. Politch

Dept. of Physics and Dept. of Aeronautical Engrg., Technion City, Haifa, Israel, Israel J. Tech., 18 (5), pp 275-280 (1980) 9 figs, 13 refs

Key Words: Vibration analysis, Holographic techniques, Speckle metrology techniques, Optical methods

Time average holographic reconstruction describes a family of fringes, proportional to contours of equal height of vibration, without being able to identify directly the "hills" and the "valleys" of the vibrating object. Time average speckle shearing interferometric reconstruction describes another family of fringes, proportional to the contours of equal slope of vibration. Combining the two families of fringes, it is possible to define at every point of a vibrating surface the amplitude and the relative phase of the mechanical vibration.

81-2648
The Acoustics of Violin Plates

C.M. Hutchins

Scientific American, 245 (4), pp 171-186 (Oct 1981)

Key Words: Violins, Musical instruments, Natural frequencies, Mode shapes, Measurement techniques

Modern tests of the vibrational properties of the unassembled top and back plates of a violin are described.

81-2649
Qualifying Fixtures for Shaker Control with a Micro-modal Analyzer

L. Enochson and P.J. Traveaux

Time Series Associates, Palo Alto, CA, TEST, 43 (4), pp 14-19, 22 (Aug/Sept 1981) 15 figs, 4 tables

Key Words: Test facilities, Shakers, Vibration analysis

In a laboratory specializing in environmental vibration qualifications, a specially designed test fixture was found to cause unusual vibrations. Modal survey performed on the test fixture is described and solutions are given.

81-2650
Measurement of Transmission Loss of Panels by the Direct Determination of Transmitted Acoustic Intensity

M.J. Crocker, P.K. Raju, and B. Forssen

Ray W. Herrick Labs., School of Mech. Engrg., Purdue Univ., West Lafayette, IN, Noise Control Engrg., 17 (1), pp 6-11 (July-Aug 1981) 8 figs, 21 refs

Key Words: Panels, Sound transmission loss, Measurement techniques

A new method for the determination of the transmission loss of panels has been developed. This method involves the measurement of the incident and transmitted acoustic intensities. The incident intensity is determined from measurements of the space-averaged sound pressure level in a reverberation room on the source side of the panel. The transmitted intensity is measured directly, using a two-microphone technique. One advantage of this new method is that it uses one reverberation room instead of two as used in the conventional transmission suite method. Another advantage is that it makes possible the identification of the energy transmitted through different parts of composite panels.

DYNAMIC TESTS
(Also see Nos. 2585, 2587)

81-2651
Digital Experimental Techniques Applied to Low Frequency Shake Phenomena

J.M. O'Keeffe, W.G. Sutcliffe, I. Scheelke, and U. Proepper
SDRC-Engineering Services (UK/Scan), Ltd., SAE
Paper No. 810094

Key Words: Steering gear, Vibration control, Low frequencies, Structural modification effects, Automobiles

Digital experimental techniques have been used to investigate the dynamic behavior of vehicles. A test program applied these techniques to provide design insight into low frequency shake phenomena. Operating tests defined the forces responsible for low frequency shake using narrow band spectra and order tracking techniques. Total deformation patterns were measured under operating conditions to determine the controlling elements participating in the vibration perceived at the steering wheel. Modal testing of the vehicle provided a mathematical model of the car over the frequency range 10-50 Hz. This model predicted the effect of modifications to the vehicle before they were implemented. The change in steering column response was monitored to assess the effect of these changes. Analytical predictions were confirmed by testing the modified vehicle.

81-2652

Digital Numerically Controlled Oscillator

A. Cellier, D.C. Huey, and L.N. Ma
NASA, Lyndon B. Johnson Space Ctr., Houston,
TX, U.S. PATENT-4 241 308, 8 pp (Dec 23, 1980)

Key Words: Oscillators, Computer-aided techniques

The frequency and phase of an output signal from an oscillator circuit are controlled with accuracy by a digital input word. Positive and negative alterations in output frequency are both provided for by translating all values of input words so that they are positive. The oscillator reference frequency is corrected only in one direction, by adding phase to the output frequency of the oscillator. The input control word is translated to a single algebraic sign and the digital 1 is added thereto. The translated input control word is then accumulated.

81-2653

Designing Perturbed Test Tracks for Evaluating Rail Vehicle Dynamic Performance

R. Brantman, A.B. Boghani, and A.D. Little
Rail Dynamics Projects, Structures and Mechanics

Branch, Transportation Systems Ctr., Cambridge,
MA, ASME Paper No. 81-RT-7

Key Words: Railroad cars, Dynamic tests, Test facilities

Perturbed tracks provide a controlled means for evaluating the performance of rail vehicles in various dynamic modes, such as hunting, rock-and-roll, pitch-and-bounce, yaw-and-sway, and dynamic curving. This paper describes a systematic approach for designing such tracks and illustrates the methodology as it has been applied to the preliminary design of the tangent and curved perturbed tracks for the stability assessment facility for equipment.

81-2654

Harmonic Optimization of a Periodic Flow Wind Tunnel

J.P. Retelle, Jr., J.M. McMichael, and D.A. Kennedy
U.S. Air Force Academy, CO, J. Aircraft, **18** (8), pp
618-623 (Aug 1981) 7 figs, 1 table, 10 refs

Key Words: Test facilities, Wind tunnels, Periodic excitation

This work describes a wind-tunnel modification designed to superpose on the mean velocity sinusoidal longitudinal velocity fluctuations with minimal harmonic content. The technique is presented in light of a theoretical analysis of the low-frequency performance illustrating how harmonic suppression can be achieved with this particular design. Velocity fluctuations are produced by a system of primary rotating vanes and a bypass containing a secondary set of rotating vanes. Experimental data on tunnel performance are also presented. A significant reduction of the second harmonic content of the free-stream velocity oscillations was achieved by adjustment of the bypass flow.

DIAGNOSTICS

(Also see No. 2679)

81-2655

The Role of Sum and Difference Frequencies in Rotating Machinery Fault Diagnosis

R.L. Eshleman

Vibration Inst., Clarendon Hills, IL, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 145-149, 5 figs, 4 refs

Key Words: Diagnostic techniques, Rotating machinery, Sum and difference frequencies

Increased complexity of rotating machinery and demands for higher speeds and greater power have created complex vibration problems. Instrumentation is now available to perform sophisticated frequency analyses of complex vibration signals. This paper is concerned with correlating machinery faults to sum and difference frequencies. Such phenomena as misalignment, antifriction bearing and gear defects, oil whirl, rubs, trapped fluid, and mass unbalance can often be related to sum and difference frequencies.

81-2656

Fault Diagnosis of Gears Using Spectrum Analysis J.I. Taylor

Vibration Specialists, Inc., Tampa, FL, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 163-168, 9 figs, 3 refs

Key Words: Diagnostic techniques, Gears, Spectrum analysis, Sum and difference frequencies

Procedures for identifying gear defects and gear meshing problems are described. A defective tooth or teeth generate and excite specific frequencies and pulses. Analysis of the time signal, spectrum frequencies, shape, amplitude, and sum and difference frequencies will reveal which gears have defective teeth, the number of defective teeth on each gear, the number of gears that have defective teeth, and the location of defective teeth with respect to some reference point. The importance of early identification of gear problems is stressed. An actual case history is presented.

81-2657

Advances in the Application of Cepstrum Analysis to Gearbox Diagnosis

R.B. Randall

Brüel & Kjaer, Naerum, Denmark, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 169-174, 7 figs, 7 refs

Key Words: Diagnostic techniques, Gearboxes, Cepstrum analysis

A review of the experience gained in the application of the cepstrum technique to the identification of families of uniformly spaced sidebands in gearbox vibration spectra is

given. After a discussion of the types of faults which give rise to such sidebands, a number of practical points in the calculation and interpretation of the cepstrum are discussed. Making use of a number of practical examples, the advantages of the cepstrum are elucidated with respect to diagnostic power and repeatability (lack of sensitivity to secondary effects).

81-2658

A New Analysis Procedure for Noise and Vibration Diagnosis of Rotating Machinery

G. Hauser

Ingenieurbüro f. Technische Akustik, W. Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 381-387, 13 figs

Key Words: Diagnostic techniques, Rotating machinery, Noise source identification, Fourier analysis

The time-synchronous time-window analysis is used for noise and vibration diagnosis especially when very compact constructions with a high degree of pulses in noise behavior are examined. In order to locate noise sources, the vibrations of several channels are analyzed in short takes, so that there is an exact coordination with the mechanical process of the machine. The synchronization procedure is achieved through an angle encoder which controls the analyzing system, so that the parts of the mechanical processes are in effect close to the shaft angle in question with an exactitude of 0.1° angle and therefore independent of speed.

81-2659

Investigating Bearing Failures

J.K. Bailey, L.R. Stenander, and R.C. Cooper

TRW Bearings Div., Jamestown, NY, Power Transm. Des., 23 (8), pp 29-33 (Aug 1981)

Key Words: Bearings, Ball bearings, Failure analysis

By studying photographs, much can be learned about premature ball bearing failure that would otherwise be difficult to communicate. A graphic representation of common conditions is presented to help determine some sources of difficulty.

BALANCING

(Also see No. 2532)

81-2660

Protect Against Large Rotor Unbalance

M.L. Adams

Univ. of Akron, OH, Power, 125 (7), pp 52-54 (July 1981) 6 refs

Key Words: Bearings, Rotors, Unbalanced mass response

Two catastrophic failures initiated by large rotor unbalance in turbine/generators with fixed-arc journal bearings in fossil-fired plants are described. The data obtained by a nonlinear vibration analysis suggests that such failures could be prevented by pivoted-pad bearings.

81-2661

A Unified Approach to Flexible Rotor Balancing: Outline and Experimental Verification

M.S. Darlow, A.J. Smalley, and A.G. Parkinson

Mechanical Technology, Inc., Latham, NY, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 437-444, 6 figs, 3 tables, 13 refs

Key Words: Balancing techniques, Rotors, Flexible rotors, Unified balancing approach, Influence coefficient method, Modal balancing technique

The logical development of an improved balancing procedure is to incorporate certain features of both the influence coefficient and modal methods to combine the advantages of each while eliminating the corresponding disadvantages. Such a unified approach, Unified Balancing Approach (UBA) has been developed and verified experimentally. In this paper, the influence coefficient and modal methods are reviewed to the extent necessary to provide the basis for the unified approach. The UBA procedure is outlined emphasizing its relationship to the parent techniques, and experimental results are presented which verify the effectiveness of this balancing method and illustrate its advantages in a practical application.

81-2662

Development of High-Speed Balancing Technology - Part 1 - Effects of Laser Metal Removal on Material

Properties and Part 2 - Balancing of Supercritical Shaft under Torque Load

R. DeMuth and E. Zorzi

Mechanical Technology, Inc., Latham, NY, Rept. No. NASA CR-165314, 93 pp (Jan 1981)

Key Words: Balancing techniques, Rotors, Flexible rotors

This report presents the tasks performed in the continuous high-speed balancing technology investigation to determine the effects of laser material removal on material properties and establish a balancing methodology that could control unbalance response with the application of axial torque, evaluate this methodology by experimental testing, and compare predicted and experimental results. Also covered in this report is the development, implementation, and testing of an influence coefficient approach to balancing a long, slender shaft under applied-torque conditions.

81-2663

Automatic Balancing of Rotors

A.A. Gusarov and L.N. Shatalov

GOSNII Mashinovedenia, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 457-461, 3 figs, 2 refs

Key Words: Rotors, Balancing techniques, Computer-aided techniques

Methods of automatically balancing rotors are classified. Two methods currently in use are described and some of their limitations outlined. A detailed description is given of a new technique employing a controllable electrohydraulic impact to discharge rapidly solidifying liquids on to the light side of an unbalanced rotor.

81-2664

Automatic Balancing of Grinding Wheels

H. Kaliszer

Mech. Engrg. Dept., Univ. of Birmingham, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 421-426, 8 figs, 11 refs

Key Words: Balancing techniques, Wheels, Grinding machinery, Computer-aided techniques

A detailed analysis is given of the existing balancing methods with special emphasis of automatic methods including an adaptive control of the balancing cycle. General economic aspects of selecting the most suitable balancing procedure is also given.

81-2665

Balancing of a Double Overhung Compressor with Skewed Wheels and a Bowed Shaft

D.J. Salamone, E.J. Gunter, and L.E. Barrett
Centritech Corp., Houston, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 259-264, 10 figs, 4 tables, 13 refs

Key Words: Rotors, Compressors, Balancing techniques

This paper includes the effects of a bowed shaft and skewed impeller wheels on the dynamic response and balancing of a double overhung compressor operating near the third critical speed. It is demonstrated that a two plane balance with a single correction weight at each impeller is insufficient to balance this rotor throughout the entire speed range. However, the system can be successfully balanced by the simultaneous application of couple corrections at each of the two overhung impellers.

81-2666

Balancing Flexible Rotors as a Problem of Mathematical Programming

M. Balda
Central Res. Inst., SKODA National Corp., Czechoslovakia, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 253-257, 1 fig, 2 tables, 15 refs

Key Words: Rotors, Flexible rotors, Balancing techniques, Minimax technique

It is shown that the problem of balancing flexible rotors is a problem of minimax, which is of a nonlinear nature in the general case. It may be solved either by algorithms of mathematical programming or by special algorithms for nonlinear minimax. There are cases for which the problem remains linear within particular iteration steps and may be solved as an L_p -approximation over a complex domain.

81-2667

Balancing of Flexible Rotor with Variable Mass

L.J. Cvetičanin
Technic of Sciences, V. Vlahovića, Novi Sad, Yugoslavia, Mech. Mach. Theory, 16 (5), pp 507-516 (1981) 14 figs, 18 refs

Key Words: Rotors, Flexible rotors, Balancing techniques

A method is given for balancing a flexible rotor with variable mass by use of a method for balancing a flexible rotor with constant mass. The result is a counterweight whose static mass moment varies with time.

81-2668

Processing Surplus Information in Computer Aided Balancing of Large Flexible Rotors

J. Drechsler
Balancing and Vibration Control Dept., ASEA, Sweden, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 65-69, 1 fig, 1 table, 5 refs

Key Words: Balancing techniques, Computer aided techniques, Rotors, Flexible rotors

The theory of flexible rotor balancing has thoroughly investigated the minimum number of balancing planes and the minimum amount of information necessary to successful rotor balancing. Practical experience shows, however, that a consistent consideration of surplus balancing planes and surplus information yields much better results and cuts down the production time considerably. Advanced averaging techniques on surplus trial runs and surplus balancing speeds yield a reliable influence coefficient matrix and can even be used to improve the right hand side of the equation system. The continual check on the pivot element size during the elimination process reveals how many and which planes are most suitable to reduce the vibration level. The surplus planes can be used to cut down the magnitude of the balancing weights, thus indirectly improving the rotor performance at operating speed and overspeed considerably.

81-2669

Determination of the Unbalance and the Dynamic Characteristics of a Flexible Rotor under Non-Stationary Conditions

L.N. Shatalov

GOSNII Mashinovedeniya, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 453-456, 2 figs, 9 refs

Key Words: Rotors, Flexible rotors, Balancing techniques

The determination of the unbalance distribution in a flexible rotor is the most difficult part of the balancing process. Investigations in this field are usually based on considerations of stationary or quasi-stationary vibrations. However, results derived by assuming a rotor to have a constant angular velocity may turn out to be not very acceptable, even for a relatively slow passage of the rotor through its critical speed. Such a divergence between the mathematical model and the actual behavior of a rotor system may give rise to errors in the determination of the unbalance distribution in the rotor. An investigation of the dynamic characteristics of flexible rotors in terms of an amplitude-phase-frequency characteristics analysis for a fast rotor transition through a critical speed is described. The rotor behavior is described by means of differential equations for non-stationary vibrations which are solved in terms of the asymptotic method of Bogolubov and Mitropolsky.

MONITORING

81-2670

Monitoring Rolling Contact Bearings under Adverse Conditions

A.G. Ray

Machinery Health Monitoring Group, Inst. Sound Vib. Res., Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 187-194, 8 figs, 8 refs

Key Words: Monitoring techniques, Rolling contact bearings, Bearings

A significant proportion of rolling contact bearings must be monitored under conditions that can only be considered as adverse. Low and ultra high speeds, difficulty of access and the presence of other more powerful vibration sources are three of the more commonly met situations. In these the ability of currently used techniques to detect damage falls dramatically. The author considers aspects of the above mentioned problems; first describing in some detail the physical nature of the problem, suggesting some solutions and giving two examples of successful detection: the first at low speed, less than 1000 DN, and the second of a gas turbine main bearing failure. The latter is perhaps the most interesting as it was achieved by vibration analysis of the signal from an accelerometer on the outer casing and so combined three of the worst situations.

81-2671

The Specification and Development of a Standard for Gearbox Monitoring

R.M. Stewart

Machinery Health Monitoring Group, Inst. Sound Vib. Res., Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 353-358, 3 figs, 1 table, 5 refs

Key Words: Monitoring techniques, Gear boxes

The principal objective of this paper is to "float" the idea of a monitoring standard for gearboxes. It is important to understand what such a term means in condition monitoring at the present time. It is a logical way of approaching the gearbox by appreciating the general nature of its problem, by defining and possibly proscribing the application of the various techniques at our disposal, and by laying out the sequence of steps that might be taken on the path towards implementation of a standard procedure. This paper has been written with machinery managers in mind rather than technicians in vibration analysis.

81-2672

Fine Tuning Mechanical Design

D. McCormick

Des. Engrg., 52 (8), pp 19-34 (Aug 1981) 6 figs

Key Words: Monitoring techniques, Measuring instruments

Machinery health monitoring instrumentation and its operation is described.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 2608)

81-2673

A Finite Element Formulation for Fluid-Structure Interaction in Three-Dimensional Space

R.F. Kulak

Reactor Analysis and Safety Div., Argonne Natl. Lab., Argonne, IL, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 183-190 (May 1981) 13 figs, 2 tables, 10 refs

Key Words: Interaction: structure-fluid, Finite element technique, Fluid-filled containers

A development is presented for a three-dimensional hexahedral hydrodynamic finite-element. Using trilinear shape functions and assuming a constant pressure field in each element, simple relations are obtained for internal nodal forces. Because the formulation is based upon a rate approach it is applicable to problems involving large displacements. This element is incorporated into an existing plate-shell finite element code. Diagonal mass matrices are used and the resulting discrete equations of motion are solved using an explicit temporal integrator. Results for several problems are presented which compare numerical predictions to closed form analytical solutions. In addition, the fluid-structure interaction problem of a fluid-filled, cylindrical vessel containing internal cylinders is studied.

MODELING TECHNIQUES

(Also see Nos. 2523, 2631)

81-2674

Simulation of Earthquake Ground Motions Using Autoregressive Moving Average (ARMA) Models
N.W. Polhemus and A.S. Cakmak

Dept. of Civil Engrg., School of Engrg. and Applied Science, Princeton Univ., Princeton, NJ, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 343-354 (July-Aug 1981) 7 figs, 6 tables, 11 refs

Key Words: Simulation, Earthquake simulation, Seismic excitation

Parsimonious representations of recorded earthquake acceleration time series are obtained by fitting stationary autoregressive moving average models after a variance-stabilizing transformation. Simulated acceleration series are then constructed by generating realizations from the fitted stationary models and applying the reverse transformation. As demonstrated on three components of a typical series, the response spectra for the observed and simulated series show good agreement for periods of less than eight seconds. The model parameters for the three components are very similar, suggesting a consistency which could be useful for identifying site-specific characteristics.

81-2675

Basic Course in Finite-Element Analysis - Advanced Techniques

N.F. Rieger and J.M. Steele

Stress Technology Inc., Rochester, NY, Machine Des., 53 (17), pp 97-100 (July 23, 1981)

Key Words: Finite element technique

The application of finite element technique for dynamic analysis is described.

NUMERICAL METHODS

81-2676

A New Branching Technique for the Static and Dynamic Analysis of Geared Systems

L.D. Mitchell

Mech. Engrg. Dept., Virginia Polytechnic Inst. and State Univ., Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 37-42, 5 figs, 2 tables, 13 refs

Key Words: Gears, Branched systems, Transfer matrix method

The dynamic analyses of gear-driven drive systems for their dynamic response have traditionally been done by equivalent dynamic system methods. This method and other nodal-based methods cause excessive computational bookkeeping. This paper proposes the use of multi-rotored transfer matrices. The rotors are coupled by a modified Hibner-type transfer matrix at each gear mesh. This method automatically includes the detailed bookkeeping within the matrix operations. The theory is presented, a mesh transfer matrix developed, and a benchmark example solved by conventional means and by the new coupling method. Numerical results are presented for the case of machining error in the gear teeth.

STATISTICAL METHODS

81-2677

Principle of Supplementarity of Damping and Isolation in Noise Control

G. Maidanik

David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD, *J. Sound Vib.*, **77** (2), pp 245-250 (July 22, 1981) 2 figs, 8 refs

Key Words: Statistical energy analysis, Noise reduction, Damping effects, Isolation

The elements of the statistical energy analysis of a complex dynamic system are briefly reviewed. The explicit form of the analysis is given for a complex consisting of two basic dynamic systems. The analysis is cast in a form that underlies the principle of supplementarity of damping and isolation. Briefly, the principle states that in situations in which the application of either damping or isolation to selected strategic portions of a complex dynamic system does not perform satisfactorily in controlling a noise problem, the supplemental application of damping and isolation may perform effectively.

PARAMETER IDENTIFICATION

81-2678

Non-Parametric Identification of a Class of Non-Linear Close-Coupled Dynamic Systems

F.E. Udawadia and C.-P. Kuo

Univ. of Southern California, Los Angeles, CA, *Intl. J. Earthquake Engrg. Struc. Dynam.*, **9** (4), pp 385-409 (July-Aug 1981) 11 figs, 6 tables, 29 refs

Key Words: System identification techniques

A non-parametric identification technique for the identification of arbitrary memoryless non-linearities has been presented for a class of close-coupled dynamic systems which are commonly met within mechanical and structural engineering. The method is essentially a regression technique and expresses the nonlinearities as series expansions in terms of orthogonal functions. Whereas no limitation on the type of test signals is imposed, the method requires the monitoring of the response of each of the masses in the system. The computational efficiency of the method, its easy implementation on analogue and digital machines and its relative insensitivity to measurement noise make it an attractive approach to the non-parametric identification problem.

81-2679

The Integration of Nonlinear Stochastic Systems with Applications to the Damage and Ambiguity Identification

W. Wedig

Z. angew. Math. Mech., **61** (1), pp 7-20 (Jan 1981) 7 figs, 10 refs

Key Words: System identification techniques, Diagnostic techniques

The paper investigates nonlinear stochastic systems with piecewise linear characteristics whose multi-dimensional distribution densities are piecewise gaussian and therefore exactly calculable taking into account the necessary continuity and normalization conditions. Applying this approach to a cracked bending oscillator, a spectral analysis is performed leading to the new phenomenon that the one degree of freedom system possesses two resonances the distance of which is a measure for the damage extension.

DESIGN TECHNIQUES

81-2680

Design Sensitivity Analysis of Planar Mechanism and Machine Dynamics

E.J. Haug, R. Wehage, and N.C. Barman

Materials Div., College of Engrg., Univ. of Iowa, Iowa City, IA, *J. Mech. Des., Trans. ASME*, **103** (3), pp 560-570 (July 1981) 8 figs, 5 tables, 14 refs

Key Words: Design techniques, Plane mechanisms, Optimum design, Computer aided techniques

A method of formulating and automatically integrating the equations of motion of quite general constrained dynamic systems is presented. Design sensitivity analysis is carried out using a state space adjoint variable method that has been employed extensively in optimal control and structural design optimization. Both dynamic analysis and design sensitivity analysis formulations are automated and numerical solution of state and adjoint differential equations are carried out using a stiff numerical integration method that treats mixed systems of differential and algebraic equations. A computer code that implements the method is applied to two numerical examples.

COMPUTER PROGRAMS

81-2681

Desktop Instruments for Modal Analysis

L. Enochson

Time Series Associates, Palo Alto, CA, Mach. Des., 53 (10), pp 81-86 (May 7, 1981)

Key Words: Measuring instruments, Modal analysis

Microcomputer-based desk top modal analyzers are described which can be operated by individuals unfamiliar with computer programming. In a typical modal analysis, a stick-figure model is developed to represent the geometry of the structure. The structure is then excited and the vibration data fed from transducers into the analyzer. The analyzer displays frequency-response functions from which the user determines the structural resonances where the largest deflections are produced. The analyzer then displays the animated mode shapes for these selected frequencies. By observing how the structure deforms for each of the various modes, the analyst can evaluate the stability of the structure and modify it if necessary to damp out excessive vibration.

81-2682

Evaluation of ADINA. Part I. Theory and Programing Descriptions

T.Y. Chang and J. Padovan

College of Engrg., Akron Univ., Akron, OH, Rept. No. AUE-801, 135 pp (June 8, 1980)

AD-A096 678

Key Words: Computer programs, Finite element technique

An evaluation of 1977 ADINA, a general purpose nonlinear finite element program, was conducted. The evaluation work consists of the review of its theoretical basis, nonlinear static and dynamic solution algorithms, and program architecture. A discussion of the program is made with respect to its nonlinear analysis capability and limitations.

81-2683

Evaluation of ADINA. Part II. Operating Characteristics

J. Padovan and T.Y. Chang

College of Engrg., Akron Univ., Akron, OH, Rept. No. AUE-802, 158 pp (June 8, 1980)

AD-A096 681

Key Words: Computer programs, Eigenvalue problems, Finite element technique

An advanced evaluation of the various solution algorithms available in the 1977 ADINA was made. The main objective

of the evaluation work is to assess the inherent characteristics of the nonlinear static, dynamic and eigenvalue solution branches of the program. Several benchmark problems were run to establish the numerical characteristics of the solution algorithms adopted by ADINA.

81-2684

Truck and Tractor-Trailer Dynamic Response Simulation, Volume 1. Summary Report

T.D. Gillespie, C.C. MacAdam, G.T. Hu, J. Bernard, and C. Winkler

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-85-1, FHWA-RD-79-123, 22 pp (Dec 1980)

PB81-174526

Key Words: Computer programs, Articulated vehicles, Ride dynamics, Braking effects

A computer program for simulating the braking and directional response of heavy vehicles has been developed for the Federal Highway Administration as a tool for investigation of the effects of increased truck size and weight. Designated as the 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1,' the program is capable of simulating trucks, tractor-semitrailers, doubles and triples combinations. Modeling for the vehicle components has been adapted from earlier simulations produced under sponsorship of the Motor Vehicle Manufacturers Association.

81-2685

Truck and Tractor-Trailer Dynamic Response Simulation, Volume 2. Technical Report

T.D. Gillespie, C.C. MacAdam, G.T. Hu, J. Bernard, and C. Winkler

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-85-2, FHWA-RD-79-124, 130 pp (Dec 1980)

PB81-174534

Key Words: Computer programs, Articulated vehicles, Ride dynamics, Braking effects

A computer program for simulating the braking and directional response of heavy vehicles has been developed for the Federal Highway Administration as a tool for investigation of the effects of increased truck size and weight. Designated as the 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1,' the program is capable of simulating

trucks, tractor-semitrailers, doubles and triples combinations. Modeling for the vehicle components has been adapted from earlier simulations produced under sponsorship of the Motor Vehicle Manufacturers Association.

form in FORTRAN. The results of NORM2L are compared with those of other computer programs.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

81-2686

Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:VI. Volume 3. User's Manual

T.D. Gillespie, C.C. MacAdam, and G.T. Hu
Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-38-1, FHWA-RD-79-125, 276 pp (Dec 1980)
PB81-174542

Key Words: Computer programs, Articulated vehicles, Ride dynamics, Braking effects

This document is a User's Manual for the computer-based mathematical simulation program entitled 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:VI' developed in 1979 by the Highway Safety Research Institute/University of Michigan. This manual provides an introduction to the simulation program with a description of its external characteristics sufficient for a user to submit a run and interpret the output obtained.

81-2687

NORM2L: An Interactive Computer Program for Acoustic Normal Mode Calculations for the Pekeris Model

D.D. Ellis
Defence Research Establishment Atlantic, Dartmouth, Nova Scotia, Rept. No. DREA-TM-80/K, 74 pp (Dec 1980)
AD-A096 548

Key Words: Computer programs, Normal modes, Elastic waves, Wave propagation, Sound propagation, Underwater sound

The interactive computer program, NORM2L, calculates the discrete normal modes and acoustic propagation loss for the Pekeris model of the ocean. The Pekeris model is a simple two-layer model in which the two layers represent the sea-water and seabed. For many shallow-water environments, the model is a reasonable approximation to the actual physical situation and can be used to investigate acoustic propagation at low frequencies. For ease of future expansion and modification, the program NORM2L is written in modular

81-2688

Vibrations in Rotating Machinery

Proc. of Second Intl. Conf. held at Churchill College, Cambridge, UK on Sept 1-4, 1980, organized by the Applied Mechanics Group of the Institution of Mechanical Engineers, 461 pp

Key Words: Proceedings, Rotating machinery, Bearings, Shafts, Mechanical drives, Gear drives, Balancing techniques

Papers presented at this conference include the seismic response of flexible rotors, modal dynamic simulation of flexible shafts in hydrodynamic bearings, drive trains in printing machines, vibration spectra from gear drives, balancing of flexible rotors as a problem of mathematical programming, and many others. Abstracts of individual papers are listed in the appropriate sections of this issue of the Digest.

TUTORIALS AND REVIEWS

81-2689

A 'Road Map' for Stress Analysis

T.G. Krulick
Fuller Co., Bethlehem, PA, Mach. Des., 53 (18), pp 139-143 (Aug 6, 1981)

Key Words: Stress analysis

Procedures for solving various stress problems are presented by means of three charts. Chart A shows how to handle static loads in both brittle and ductile materials. Chart B covers reversing loads on ductile structures. Chart C treats fluctuating loads, uniaxial or combined, in ductile materials.

81-2690

Three Traps to Avoid in Noise Control

T.H. Rockwell

Acoustical Consultant, Chesterland, OH, Plant
Engrg., 35 (16), pp 99-100 (Aug 6, 1981) 2 figs

Key Words: Noise reduction, Machinery vibration, Machinery noise

The aim of this article is to clarify some of the acoustics fundamentals of machinery noise control. It briefly discusses sound absorption, machinery vibration and noise measuring instrumentation.

**CRITERIA, STANDARDS, AND
SPECIFICATIONS**

81-2691

Logical Analysis of Tentative Seismic Provisions

J.R. Harris, S.J. Fenves, and R.N. Wright

Ctr. for Building Tech., U.S. Dept. of Commerce,
Natl. Bureau of Standards, Gaithersburg, MD, ASCE
J. Struc. Div., 107 (ST8), pp 1629-1641 (Aug 1981)
6 figs, 2 tables, 4 refs

Key Words: Standards and codes, Buildings, Seismic design, Earthquake resistant structures

A study is described of the format and expression of the Tentative Provisions for the Development of Seismic Regulations for Buildings developed by the Applied Technology Council. The methods of analysis employed provide objective measures of clarity, completeness and consistency, as well as an alternative formal representation with which to examine the correctness of the provisions. The formal representation of the seismic provisions and the findings of the analysis will assist those concerned with the future development of the provisions and their implementation within the various national standards and model codes.

ANNUAL AUTHOR INDEX

- Aasen, J.O. 2264
 Abbott, D.R. 2117
 Abdel-Ghaffar, A.M. . . . 11, 1596,
 1831
 Abdelhafez, F.A. 300
 Abdel-Rahman, A.Y.A. . . . 1068
 Abdel-Rohman, M. 2310
 Aboudi, J. 2031
 Aboul-Ella, F. 732
 Abraham, D. 1187, 1189
 Abrahamson, A.L. 1033, 1293
 Abrahamson, G.R. 637
 Achenbach, J.D. 388, 1967, 2473
 Acosta, A.J. 519, 951
 Adachi, T. 1494
 Adams, D.R. 2109
 Adams, M. 221
 Adams, M.L. 723, 864, 1801,
 2660
 Adams, M.L., Jr. 3, 1538
 Adams, R.D. 1103, 1660
 Affenzeller, J. 1114
 Agar, T.J.A. 922
 Agata, H. 1168
 Agbabian, M.S. 180
 Agrawal, A.B. 1963
 Agrawal, P.N. 2542
 Agrone, M. 1393
 Aguilar, F. 1740
 Ahlbeck, D.R. 272, 274
 Ahmadi, G. 828
 Ahmed, H.U. 1601
 Ahmed, K.M. 892
 Ahrlin, U. 49
 Ahuja, K.K. 170, 2234
 Aicher, W. 1084, 1583
 Aida, T. 2305
 Akamatsu, N. 1710
 Akay, A. 2456
 Akins, H. 578
 Akkas, N. 1007
 Akkok, M. 585
 Albrecht, H. 302
 Albrecht, P. 1938, 2438
 Albritton, G.E. 1252
 Alderson, M.A.H.G. 243
 Alexander, C.M. 1490
 Alfredson, R.J. 168, 2183
 Ali, R. 984
 Allaire, P.E. 69, 71, 72, 76, 315,
 493, 500, 586, 1523, 2584
 Allan, A.B. 1430
 Allen, R.R. 1462, 2486
 Allen, R.W. 1232
 Allotey, I.A. 780
 Alstead, C.J. 1205
 Alwar, R.S. 117
 Amazigo, J.C. 2121
 Amini, A. 2195
 Anagnostopoulos, S.A. 2383
 Anand, K.K. 2482
 Anderson, G.S. 149
 Anderson, J.C. 1907, 2387, 2598
 Anderson, L.R. 2266
 Anderson, M.S. 1909
 Ando, Z. 1717
 Andreau, C. 37, 928
 Andrew, C. 809
 Andry, A.N., Jr. 2208
 Andrzejewski, M. 2431
 Aneja, J.K. 2539
 Angelides, D.C. 739, 885
 Anspach, W.F. 1537
 Antonelli, R.G. 1821
 Antonopoulos-Domis, M. . . . 1368
 Aomura, S. 2143
 AppaRao, T.A.P.S. 2331
 Arendts, J.G. 216
 Argyris, J.H. 1084, 1583
 Ariman, T. 368, 796, 1785
 Aristizabal-Ochoa, J.D. 384
 Armstrong, G. 1580
 Armstrong, R.E. 149
 Arnesen, T. 1912
 Arora, A. 2469
 Arzoumanidis, S.G. 730
 Asano, N. 1126
 Ascari, A. 1236
 Asfar, K.R. 1063
 Ashby, G.C., Jr. 1970
 Askar, A. 819, 1319, 1827, 2433
 Aslam, M. 1277, 1279
 Aso, K. 2381
 Assedo, R. 268
 Astley, R.J. 1959, 1960
 Atkinson, C. 662
 Atkinson, J.T. 172
 Atkinson, K. 137
 Atluri, S.N. 459, 460, 539, 836
 1130, 1131, 1132, 2637
 Atmatzidis, D.K. 2311
 Atwal, S.J. 984
 Au, Y.H.J. 231
 Aubrun, J.N. 421
 Auckland, D.W. 1724
 Auconi, F. 1349
 Auer, B.M. 959
 Auersch, L. 1846
 Austin, S.C. 734
 Au-Yang, M.K. 2316
 Avezard, L. 2341
 Awaji, H. 1284
 Axelrod, M. 2229
 Axt, W. 1855
- B**
- Babcock, C.D. 404, 784
 Babcock, C.D., Jr. 1940, 2406
 Bacelon, M. 911
 Bachschmid, N. 2513
 Baczynski, R. 1605
 Badgley, R.H. 706
 Bagci, C. 2053, 2427
 Bailey, C.D. 2144
 Bailey, D.A. 1217
 Bailey, J.K. 2659
 Bailey, J.R. 813
 Bailey, P.B. 1766
 Bainum, P.M. 296
 Bajak, I.L. 1514
 Bakaysa, B. 1116
 Baker, G.K. 1536

Baker, L.	1745	Bathelt, H.	1843	Berglund, K.	49
Baker, P.F.	905	Batko, V.	1306	Bergman, L.A.	2030
Baker, W.E.	646	Battis, J.C.	2560	Berkovits, A.	1219
Bakewell, H.P., Jr.	2465	Baudin, M.	37, 928	Bernard, J.	2684, 2685
Balakrishnan, A.V.	1441	Bauer, H.F.	94, 867, 1278, 1947	Bernard, T.	163
Balasubramanian, T.S.	2	.....	2347	Berndt, W.	185
Balda, M.	2666	Bauer, J.	735	Berry, B.F.	1633
Balendra, T.	783, 1190	Baum, N.P.	1356	Berry, R.A.	717
Bail, J.H.	527	Baumeister, K.J.	624, 1292, 1506	Bert, C.W.	625, 776, 1041, 1681,
Bail, R.E.	1951	Bayliss, A.	1966	.....	1937, 2600, 2604
Bail, S.J.	270	Beaman, J.J.	2497, 2498	Berthe, D.	2112
Ballato, A.	1529	Beard, C.A.	2587	Bertrand, M.	326
Ballo, I.	1743	Beards, C.F.	999	Besancon, P.	2413
Balsara, J.P.	1252	Bechert, D.W.	141	Beskos, D.E.	423, 1082, 1901,
Baluch, M.H.	1927	Beck, R.F.	1856	.....	2024, 2164
Banda, S.S.	1867	Beck, S.A.	1104	Betts, W.S., Jr.	2315, 2549
Bandyopadhyay, P.	174	Becker, J.M.	806	Beucke, K.E.	2097, 2098
Banerjee, M.M.	1933	Becker, R.	385	Bezine, G.	989
Bannister, K.A.	552, 2163	Beckert, H.	317	Bezler, P.	1149
Bannister, R.H.	2578	Beckman, J.M.	1214	Bhandari, N.C.	350
Bannister, R.L.	2539, 2623	Beddoes, T.S.	1057	Bhashyam, G.R.	969, 2382
Banon, H.	883	Bednar, J.A.	57	Bhaskara Sarma, K.V.	2510
Bapat, V.A.	1080	Bedrosian, B.	1198	Bhat, R.B.	2140
Barbas, S.T.	2385	Beex, A.A.L.	1138, 2230	Bhat, W.V.	1613
Barbela, M.	1198	Behar, A.	810, 811, 2324	Bhattacharjee, M.C.	1520
Barez, F.	638	Behring, M.A.	561, 562	Bhattacharya, S.K.	2453
Barger, J.E.	673	Beljaev, A.K.	1122	Bhatti, M.A.	1320, 2176
Bargis, E.	6, 7	Bell, C.E.	1435	Bhushan, B.	1643
Barlow, R.E.	799	Bell, G.K.	906	Bickel, D.C.	2467
Barman, N.C.	2680	Bell, R.	994	Bickel, J.H.	1539
Barnes, G.R.	569	Bellomo, N.	230, 846	Bies, D.A.	103, 1271
Baronet, C.N.	395	Belon, B.	858	Biggs, J.M.	883, 2561
Barr, A.D.S.	1065	Beltzer, A.I.	427	Bilek, Z.	455
Barrett, D.C.	1353	Belytschko, T.	544, 862, 970	Biller, R.H.	1208
Barrett, L.E.	71, 499, 1523, 2584	Benckert, H.	606, 2593	Billings, S.A.	1775
.....	2665	Benda, B.J.	347	Billingsley, R.H.	2074
Barrows, T.M.	36, 1429	Bendat, J.S.	1995	Birchak, J.R.	480
Barry, K.E.	2270	Bender, E.K.	627	Birembaut, Y.	722
Barta, D.A.	1502	Bendiksen, O.	2101	Birlik, G.	1039
Bartholomae, R.	1469	Ben-Dor, G.	1708	Birman, V.	1264
Bartholomae, R.C.	538, 627	Benedetto, G.	2005	Birnie, S.E.	51, 817, 934, 2622
Bartlett, J.A.	1892	Benedikter, G.	1992	Bishop, C.R.	1467
Barton, C.K.	1616, 2338	Benettin, G.	844, 845	Bishop, D.E.	1214, 2342
Bartsch, O.	289	Benham, R.A.	563	Bishop, R.A.	2319
Baruch, M.	97	Benjamin, M.	2172	Bishop, R.E.D.	925, 927, 2631
Bass, R.L.	1274, 1674	Bennett, J.G.	2069	Bitter, C.	1444
Batcheler, R.P.	236, 1185, 1188,	Bennetts, R.D.	877	Bitzer, J.H.	484
.....	1189	Bentley, L.R.	1810	Bjorkman, M.	49
Batchelor, B. deV.	765	Bently, D.E.	490, 697	Black, H.F.	486, 2509
Bathe, K.	361	Benton, M.	2093, 2370	Black, R.G.	2178
Bathe, K.-J.	2274	Berengier, M.	1048	Blackwell, R.H.	1585

Q

Caplan, C.R.	1470	Chen, C.H.	405	Chu, F.H.	2048, 2089, 2269
Carden, H.D.	1872, 1873	Chen, C.K.	1916	Chu, L.	1319
Carey, R.	1629	Chen, C.S.	1364	Chu, L.L.	819, 1827
Cargill, A.M.	1860, 1957	Chen, E.P.	1527	Chu, M.L.	1677
Carlsen, C.A.	750	Chen, G.	1076	Chuang, A.	764
Carlson, H.W.	1453	Chen, J.C.	48	Chung, C.G.	2034
Carpenter, G.F.	64	Chen, J.H.	2368	Chung, H.	1661, 1678, 1942
Carter, A.D.S.	661	Chen, K.N.	1238	Chung, J.S.	1953, 1954
Caruso, H.J.	719	Chen, L.	67	Chung, J.Y.	382, 383, 2233
Caruthers, J.E.	727	Chen, N.N.S.	318	Chwang, A.T.	1422
Castelli, V.	204	Chen, P.J.	1766	Cipra, R.J.	1554, 1555
Castro, G.	255	Chen, S.S.	377, 1715, 1911	Citerley, R.	408
Caughey, T.K.	519, 951	Chen, T.	740	Citerley, R.L.	390, 1951
Cavanaugh, W.J.	245	Chen, T.W.	280, 898	Civelek, M.B.	1765
Cawley, P.	1103	Chen, Y.	278, 770	Claar, P.W., II	577
Cazier, F., Jr.	1621	Chen, Y.N.	131, 378	Clapis, A.	2753
Celep, Z.	102, 769	Chen, Y.T.	827	Clark, B.	691
Cella, A.	398	Cheng, F.Y.	2064	Clark, J.A.	171, 2646
Cellier, A.	2652	Cheng, H.S.	2113, 2114	Clark, N.H.	658
Cempel, C.	1113, 2431	Chesta, L.	938, 1623	Clarkson, B.L.	1100
Centola, N.	255	Cheung, Y.K.	1914	Clayton, S.	892
Ceranoglu, A.N.	2402, 2403, 2404	Chhappgar, A.F.	2014	Cleghorn, W.L.	2491
Cermak, G.W.	910	Chia, W.	465	Clements, D.L.	1266
Cervenak, J.G.	910	Chiang, F.P.	1273	Cline, J.E.	1229
Cevallos-Candau, P.J.	416	Chiarito, V.	1423, 2066, 2067	Clough, R.W.	860
Chabrerie, J.	373	Chien, S.	1835	Clubertson, C.R.	2625
Chadha, J.A.	82	Chiesa, M.L.	1387, 2094	Cluff, J.L.	2627
Chaiyung, L.	240, 257	Chikwendu, S.C.	2442	Coakley, W.S.	2046
Chakrabarti, P.	2541	Childs, D.W.	603, 1582, 2291, 2585	Coale, C.W.	560
Chamieh, D.	951	Childs, S.B.	603, 2585	Coats, D.W.	217
Chan, A.W.	405	Chimenti, D.E.	1305	Coenen, J.H.	125
Chan, R.H.	631	Chiou, K.L.	1759	Cohen, D.	2328
Chan, Y.-L.A.	440	Chipman, R.R.	1869	Cohen, J.K.	2626
Chand, G.	1734	Chiroio, V.	431	Cohen, N.	172
Chandra, J.	2161	Chivers, J.W.H.	1533	Colding-Jørgensen, J.	518
Chandra, S.	165, 1524	Chlodziński, J.	2187	Collard, S.	2519
Chang, C.H.	2159	Chmúrny, R.	306, 1235	Colton, D.	1508, 1562
Chang, J.C.H.	830	Cho, Y.C.	136	Combescure, A.	736
Chang, P.Y.	2336	Choi, H.S.	735	Comstock, T.R.	163
Chang, T.Y.	2682, 2683	Chombard, J.	2341	Condouris, M.A.	696
Chang, Y.W.	264	Chon, C.T.	1127	Connor, J.J.	739
Chao, C.	1031	Chonan, S.	775, 778, 1682	Connors, H.J.	130
Chao, W.C.	776, 2149, 2604	Chondros, T.G.	184	Conry, T.F.	1891, 2036
Chapkis, R.L.	933	Chopra, A.K.	773, 1597, 2537, 2541, 2543	Contreras, H.	458
Chapman, J.	2554	Chou, A.	1749	Cook, R.O.	2456
Chapman, R.B.	1609	Chow, G.C.	1486	Cooke, P.W.	1399
Chargin, M.	408	Chow, P.L.	1759	Cookson, R.A.	174, 2634
Chattot, J.J.	939	Choy, K.C.	69, 76	Cooley, D.B.	1438
Chaturvedi, G.K.	2472	Christie, A.M.	540, 543	Cooper, P.	1625
Chen, C.	24, 399, 1731			Cooper, R.C.	2659
Chen, C.C.	368, 796			Cooper, R.E., Jr.	1363

Copley, J.C. 2086
 Corley, J.E. 528
 Cornell, C.A. 260
 Cost, T.L. 2188
 Costantino, C.J. 2043, 2504
 Costello, W.J. 179
 Cotran, F.S. 2621
 Courage, J.B. 2569
 Coupland, R.O. 690
 Cowley, A. 1923
 Cox, P.A. 1274, 1674
 Coy, J.J. 2303, 2304
 Crabill, N.L. 1871
 Craggs, A. 1029
 Craig, J. 1545
 Craig, J.E. 156, 157
 Craig, M.J. 1596
 Crighton, D.G. 2142
 Craik, R.J.M. 1958
 Crance, C. 1448, 2026
 Crandall, S.H. 407, 502, 1074,
 1325, 2557
 Crane, R.L. 1305
 Crawley, E.F. 1000, 2009
 Crighton, D.G. 979
 Crocker, M.J. 1542, 2650
 Croll, J.G.A. 1008, 1683
 Crolla, D.A. 744, 745
 Cronkrite, J.D. 46
 Crouse, J.E. 875
 Crowson, R.D. 2243
 Cubitt, N.J. 91
 Cullen, W.H. 265
 Culver, C.C. 2327
 Culver, L.E. 1343
 Cummings, A. 1036, 1956
 Cummins, R.J. 1465
 Cunningham, R. 831
 Currie, I.G. 1836
 Currie, R.B. 1
 Curry, L.W. 1990
 Curti, G. 339
 Curtis, A.J. 685
 Curtis, D. 362
 Curtiss, H.C., Jr. 747
 Cutchins, M.A. 1246
 Cvetičanin, L.J. 2667
 Czarnecki, S. 2428
 Czechowicz, M. 2428

D

Dagalakis, N.G. 2250
 Dahan, C. 2340, 2341
 Dahl, G. 1547
 Dahlberg, T. 903
 Dahlke, H.J. 259
 Dale, A.K. 745
 Dale, B. 2039
 Dally, J.W. 1350
 Daly, K.J. 2251
 Dalzell, J.F. 2334
 D'Ambra, A. 2042
 Damm, W. 529
 Damms, S.M. 1140
 Dan, Y. 2595
 Daniel, B.R. 1505
 Daniel, W.J.T. 196, 842
 Daniels, J.H. 236, 237, 238, 1185
 1186, 1187, 1188, 1189
 Danner, M. 689
 Darlow, M.S. 700, 1366, 2474
 2661
 Das, A. 1128
 Das, N.C. 2453
 Das, S.N. 2453
 Das Vikal, R.C. 2204
 Dashcund, D.E. 1868
 Dassios, G. 139
 Datta, P. 1667
 Datta, S.K. 360, 1022, 1498
 Davall, P.W. 1333
 David, J.W. 1819
 Davidson, J.W. 153
 Davies, D.E. 1442
 Davies, J.C. 106, 1919, 2426
 2011
 Davies, M. 2054
 Davies, P.O.A.L. 2620
 Davies, W.G.R. 2520
 Davis, D.D. 233
 Davis, S. 1605, 2326
 Davis, S.J. 1154, 1228
 Dawe, D.J. 109, 983, 1257
 Dawson, B. 2054
 Dean, P.D. 170
 Dear, T.A. 1510
 Dease, C.W. 233
 DebChaudhury, A. 829, 1990

Dede, M. 2633
 Deel, C.C., II 976
 Deel, G.W. 1516
 Deen, R.C. 470
 DeFerrari, G. 938, 1623
 Degenkolb, H.J. 241
 Degnan, J.R. 504
 deGraaf, E.A.B. 953
 DeHoff, R. 1745
 Delale, F. 2618
 Delil, A.A.M. 953
 Deloach, R. 1862
 Delpak, R. 1005
 Delph, T.J. 413
 Demott, L.R. 1369
 Dempsey, T.K. 1863
 DeMuth, R. 2662
 Deng, R.-Y. 1870
 Dennison, E.E. 394, 526
 Denus, S. 2187
 dePater, A.D. 945
 Dereggi, A. 2012
 DeSanto, D.F. 356
 de Silva, C.W. 684, 2214
 Desjardins, R.A. 1635
 Desjardins, S.P. 1222
 Desmond, R.M. 1020
 Desmond, T.P. 2445
 de Souza, V.C.M. 1008, 1683
 Destuynder, R. 1460
 Devaux, H. 108
 Devitt, J. 439, 2464
 DeVor, R.E. 1464
 Devrieze, L. 1481
 De Wachter, L. 322
 Dharmarajan, S. 612
 Diana, G. 2513, 2581
 Diaz-Tous, I.A. 1416
 Dickens, J.M. 1426
 Dickinson, S.M. 986, 2154, 2155
 Dicus, R.L. 2432
 Diekhans, G. 1240, 1650, 1815
 2525
 Dietrich, R.A. 547
 Dilger, T. 163
 Dillon, D.B. 607
 DiMaggio, F.L. 2160
 Dimarogonas, A.D. 184, 1171
 Dimmer, J.P. 1538
 Dinyavari, M. 1835
 Dittmar, J.H. 143

Dittrich, G.	876	Dudman, A.E.	288	Elmaraghy, R.	395
Dixon, N.R.	627, 1202	Duffett, D.L.	475	El-Raheb, M.	1281, 1940, 1941
Doak, P.E.	1047	Duffy, J.	2636	. . . . .	1950, 2406
Dobbs, M.	1835	Dufour, A.	2581	El-Sayed, H.R.	319
Dobbs, M.W.	1363	Dufrane, K.	2519	El-Shafee, O.M.	250
Dobeck, G.J.	859	Duggan, T.V.	1719	Eman, K.	2059
Dobyns, A.L.	1670	Dugundji, J.	67, 2557, 1000	Emergy, J.D.	218
Dodd, V.R.	512	Duncan, A.B.	591	Emery, A.	2615
Dodlbacher, G.	1209	Dungar, R.	479	Emery, A.F.	1284, 1285, 2616
Dogan, I.U.	2580	Dunham, R.S.	2254	Endebrook, E.G.	467
Doggett, R.V.	1620	Dunn, H.J.	1752	Endo, M.	2179
Doggett, R.V., Jr.	43, 1456	Durham, D.J.	678	Engelbrecht, J.	2452
Doige, A.G.	1087	Durrans, R.F.	1069	Engin, A.E.	1007
Dokanish, M.A.	1430	Dutta, P.K.	1179	Engin, H.	2433
Dolling, D.S.	397	Dyrdahl, R.	2287	England, R.H.	2286
Dollman, J.	1727	Dzygadło, Z.	492, 1455, 2082, 2102	Engler, A.J.	640, 2008
Dombrowski, H.	611			Engrand, D.	426
Don, C.G.	1882			Ennenkl, V.	1290
Donald, G.H.	523			Enochson, L.	2649, 2681
Donaldson, I.S.	1288			Enright, W.H.	709
Donath, G.	1855			Epstein, A.	268
Done, G.T.S.	1874, 2514			Erdogan, F.	1765, 2618
Dornfeld, D.A.	2060			Ericsson, L.E.	1210
dos Reis, H.L.M.	664			Ernault, M.	40
Douglas, B.E.	1493			Erskine, J.B.	676
Dousis, D.	1541			Ertelt, H.J.	1084
Dover, W.D.	1603			Ervin, R.D.	61, 1845
Dowding, C.H.	641, 2311			Eshleman, R.L.	332, 666, 1243, 2017, 2655
Dowell, E.H.	118, 1031, 1102, 1351			Essinger, J.N.	511
Downs, B.	91, 313			Etherington, J.F.	2591
Dowrick, D.J.	1838			Etsion, I.	336, 959, 2110, 2595
Dowson, D.	506			Etter, P.C.	1569
Drago, R.J.	323, 530, 879, 1181			Ettles, C.M.McC.	585
Dragonette, L.R.	1702			Evans, J.W.	2372
Drake, M.L.	1339, 1340			Everett, D.H.	279
Dranga, M.	2272			Everett, W.D.	178, 2235
Dreadin, W.O.	2015			Eversman, W.	1959, 1960
Drechsler, J.	2668			Everstine, G.C.	364
Dreher, R.C.	308			Ewins, D.J.	203, 554, 952, 1729
Drenick, R.F.	30, 1144, 1198			. . . . .	2232, 2566
Dresden, J.	2585			Ezzat, H.A.	73
Dressel, P.	1424				
Dressman, J.B.	603				
Driels, M.R.	1049				
Driscoll, D.A.	1883				
Drosdol, J.	1846				
Du, J.-s.	1870				
Dubey, R.N.	1161				
Dubik, A.	2187				
Dubowsky, S.	2590				

Farah, A.	1928	Fleischer, C.C.	1201	Friedmann, P.	2101
Farassat, F.	311, 931	Fleiss, R.	333	Friesenhahn, G.J.	643
Farassat, R.	1612	Fleming, D.P.	508, 605	Frisk, G.V.	396
Farell, C.	1944	Fleming, J.F.	2120	Frohrib, D.A.	2115
Farmer, M.G.	1458	Flesch, R.	1081	Fryba, L.	12
Favier, D.J.	1624	Fletcher, J.D.	2588	Fujii, K.	1253
Fawcett, J.N.	234, 1817	Flipse, J.E.	1949	Fujii, M.	1649
Fedock, J.J.	2628	Florjancic, D.	228	Fujii, Y.	1648
Fehrenbach, J.P.	1910	Foutch, D.A.	1964	Fujikawa, T.	495
Feiler, C.E.	1861	Fluegge, W.	1003	Fujisawa, F.	445, 1115
Feit, D.	1676	Flynn, D.R.	150	Fujita, H.	2548
Feldmaier, D.A.	2325	Fogelquist, J.	1706	Fujita, T.	1072
Felgenhauer, H.-P.	2218	Fokkema, J.T.	848, 1303, 1698	Fujiwara, H.	1405
Felippa, C.A.	2256, 2271	Fong, J.T.	1163	Fukano, T.	226
Felsen, L.B.	193, 456	Fonseka, G.U.	2225	Fukuoka, H.	2447
Felton, L.P.	153	Fontanet, P.	913	Fukushige, K.	1291
Fenton, J.	2346	Fontenot, L.L.	2348	Fukushima, M.	2318
Fenton, R.G.	2491	Ford, D.W.	1215, 1443	Fuller, C.R.	1014, 2162, 2609
Fenves, S.J.	2691	Ford, R.A.J.	726	Fuller, H.C.	1633
Ferralli, M.W.	1471	Forell, N.F.	17	Fung, Y.T.	95
Ferrante, M.	559	Forssen, B.	2650	Funk, G.E.	122, 366
Ferry, J.M.	1316	Forward, R.L.	1337, 1338	Furgerson, R.L.	15
Fertis, D.G.	785	Fossman, R.	1475	Furudono, M.	870
Fiala, V.	422	Fost, R.	1727	Furukawa, T.	2405
Ficcadenti, G.M.	1932, 2025	Foughner, J.T., Jr.	1621		
Fick, S.E.	1348	Found, M.S.	2641		
Fidell, S.	1972	Fowler, B.G.	737		
Fiedler, S.	1892	Fox, C.H.J.	435		
Field, J.S.	1726	Fox, D.W.	113		
Fielding, L.	1367	Fox, G.L.	2267		
Fields, J.M.	941	Fox, M.J.H.	1018, 1335		
Filippi, M.	1196	Fox, R.L.	703		
Filippi, P.	1256	Foxlee, T.F.	2319		
Filliben, J.J.	2425	France, D.	2526		
Finch, R.D.	1541	Francher, P.S.	61		
Fine, T.E.	2374	Frank, L.J.	1702		
Fink, M.R.	1217	Franklin, R.E.	1504		
Finn, A.E.	510	Frankowski, G.	1730		
Fintel, M.	1195	Frarey, J.	1744		
Fiorato, A.E.	384	Frarey, J.L.	674, 1748		
Fischer, F.J.	1908	Fraser, R.C.	1083		
Fischer, J.	1432	Fraser, W.B.	1055		
Fisher, J.W.	238, 1186	Frazier, L.E.	737		
Fisher, T.A.	1185	Freddi, A.	1721		
Fitzpatrick, J.A.	1288	Freedman, A.	105		
Fjorkman, M.	52	Freiberg, R.	2243		
Flack, R.D.	72, 493, 500, 869	Freund, L.B.	2636		
	1406, 1813, 2050	Frey, J.H.	1796, 1797, 1798		
Flamand, L.	2112	Friant, C.L.	1348		
Flax, L.	148	Fricke, H.	520		
Fleeter, S.	281	Fricker, A.J.	2299		

G

Gabraiel, S.A.	2638
Gajewski, A.	975
Galford, J.E.	2316
Galgani, L.	844, 845
Galkowski, A.	2187
Gallo, A.M.	2038, 2039, 2040
Gailop, J.C.	1799
Gambet, P.S.	1813
Gambhir, M.L.	765
Gandhi, M.V.	1484
Ganesan, N.	980, 2141
GangaRao, H.V.S.	1570
Gaonkar, G.H.	1866
Garba, J.A.	48
Garcia-Gardea, E.	2306
Gardner, T.G.	1466
Garg, D.P.	36, 1429
Garg, S.C.	1627
Garg, V.K.	1561
Garner, D.R.	581, 2109
Garrison, C.J.	2072
Garro, A.	6, 7

Gasch, R.	1805	Gliebe, P.R.	1211, 2047	Gregory, D.L.	683
Gasparini, D.A.	829, 1990	Glynn, C.C.	2411	Greif, R.	746, 920, 1203, 2553
Gaukroger, D.R.	1139	Godden, W.G.	1279	Greimann, L.F.	1038
Gauthier, R.D.	837	Godel, H.	1459	Gribik, J.A.	2268
Gauvain, J.	267	Godet, M.	2112	Griesbach, T.J.	372
Gaver, D.P.	159	Goedel, H.	1622	Griffin, J.S.	572
Gay, D.	93	Goenka, P.K.	77, 761	Griffin, M.J.	53
Gaylo, K.R.	1470	Goes, M.J.	1530	Griffin, O.M.	127
Gazanhes, C.	151, 1563	Goetz, R.C.	45	Griffin, P.M.	1197
Gedeon, J.	916	Goff, R.J.	1854	Griffiths, I.D.	912
Geering, H.P.	1754	Goglia, P.R.	2036	Grigoriu, M.	1143
Geers, T.L.	1017, 2611, 1982, 2410	Gold, P.	284	Grillenberger, T.	369
Gehien, P.C.	2629	Goldberg, J.L.	658	Grinberg, N.M.	2640
Gehlen, C.	401	Golden, T.C.	2193	Groenwald, R.A.	188
Gehlen, P.C.	119	Goldman, S.	1738	Groom, N.	1672
Gelos, R.	1932	Goldschmied, F.R.	1427, 1811	Grossi, R.O.	1932, 2025, 2152
George, J.	148	Goldsmith, W.	638	.....	2153
Geradin, M.	198	Goldstein, N.A.	789	Grossman, D.T.	947
Gerardi, T.G.	2087	Göller, B.	263, 1009, 1939	Grossmayer, R.L.	1758, 2260
Geren, B.F.	1892	Gong, E.Y.	2285	Groth, K.	2055
Gergely, P.	27	Gonzalez, R.	713	Grove, C.F.	1989
Gerharz, J.J.	1991	Good, R.R.	436	Grover, A.S.	1265
Gerhold, C.H.	1614	Goodling, E.C., Jr.	794	Groves, D.	172
Gersch, W.	190, 201	Goodykoontz, J.	1450	Guan-Qing, C.	370
Geschwindner, L.F., Jr.	83	Gorman, D.G.	1178	Guenther, D.A.	814
Ghanaat, Y.	1194	Gorman, D.J.	132, 985	Guenzler, R.C.	216
Ghose, A.	1838	Gorman, V.W.	216	Guex, L.	974
Ghosh, D.P.	256	Gosele, K.	533	Guicking, D.	620
Ghosh, S.K.	1195	Gossain, D.M.	557	Guigli, J.	349
Giacofci, T.A.	2167	Gossmann, E.	429, 430	Guilbert, M.P.	1662
Gibbons, C.B.	596	Gottlieb, H.P.W.	2202	Guild, F.J.	1660
Gibbs, B.M.	106, 1919, 2426	Gottlieb, J.J.	1051	Guilinger, W.H.	1825
Gibert, P.	457	Gould, P.L.	250	Guillien, G.	2341
Gibert, R.J.	268, 373, 736	Goyder, H.G.D.	1021, 1124	Guins, S.G.	59
Gibson, W.C.	390	Gracewski, S.	2274	Gulati, J.M.	1654
Gie, T.S.	1841	Grainger, H.	2526	Gundy, W.	1835
Giergiel, J.	1306	Grant, R.J.	1478	Gunter, E.J.	71, 315, 499, 509
Gill, H.S.	2545, 2546, 2547	Grape, P.M.	47	.....	1406, 1409, 1523, 2050, 2665
Gill, K.F.	2346	Grasso, V.	1182	Guntur, R.R.	2210
Gillespie, T.D.	2684, 2685, 2686	Gratieux, E.	2340	Gupta, G.D.	194
Gillies, A.G.	2601	Graunke, K.	2057	Gupta, K.K.	1522, 1559
Gillies, D.J.	299	Graves, G.A., Jr.	833	Gupta, K.N.	2204
Gillies, J.	956	Gray, I.	1465	Gupta, R.K.	616
Ginsberg, J.H.	1696	Greathead, S.H.	2507	Gupta, S.	2543
Giorgilli, A.	844, 845	Green, D.M.	1972	Gurbuz, O.	788
Girhammar, U.A.	597	Green, I.	2110	Gusarov, A.A.	2663
Gjestland, T.	50	Green, R.E., Jr.	1348	Gutierrez, R.H.	454, 2138, 2152
Glaser, F.W.	1413	Greenan, A.F.	2641	.....	2157, 2158
Glass, B.	672	Greenburg, J.B.	2407	Guttalu, R.S.	2263
Glew, T.C.	707	Greene, G.C.	1612, 1863	Guyader, J.L.	104
		Gregory, R.A.	43	Gvildys, J.	264

Gyllenspetz, I.M. 645

H

Haas, P. 2075
Haasz, A.A. 1630
Habercorn, G.E., Jr. 1166, 1167
Haddow, J.B. 2610
Hagan, M. 182
Hagedorn, P. 962, 1245, 2261
Hagiwara, I. 2503
Hague, W.M. 1005
Hahn, E.E. 548, 549, 715
Hahn, E.J. 1638
Hahn, K.C. 1313, 1314
Hailfinger, G. 263, 1939, 2165
Haines, D.J. 2575
Haines, R.S. 335, 601
Hale, A. 1757
Hale, A.L. 1125
Hall, F.L. 51, 149, 817, 934, 2622
Hall, J.W., Jr. 1107
Hall, P.S. 2237
Hall, S.A. 2388
Hall, W., Jr. 1745
Hall, W.E., Jr. 2559
Hall, W.J. 2621
Hallam, M.G. 895
Hallauer, W.L., Jr. 420, 2266
Halle, H. 1019
Hallquist, J.O. 2282
Halloran, J.D. 698, 1361, 1693
Halpern, S. 362
Hamada, M. 1145
Hamada, T.R. 1906
Hamblen, W.R. 673
Hamburg, G. 1741
Hamid, S. 103
Hamm, C.W. 2456
Hamma, G.A. 1106
Hammerschmidt, C. 1895
Hammill, W.J. 1069
Hammond, C.E. 954, 1229
Hammond, J.K. 1431
Hamstad, M.A. 1599
Han, K.W. 2034
Han, L.Q. 724
Han, L.S. 110

Hancock, G.J. 937
Hanin, M. 1220
Hanley, M.A. 2368
Hanson, C.E. 919
Hansen, C.H. 1271
Hanson, D.B. 283, 555
Hanson, H.W. 1386
Hara, Y. 298
Hardegen, H. 1547
Harding, K.G. 1091
Hare, J.R., Jr. 1215
Haroun, M.A. 782, 1673
Harris, A.S. 632, 2342
Harris, J.R. 1398, 2691
Harris, T. 1454
Harrison, H.D. 272, 274
Harrison, I.R. 855
Harrison, R.F. 1431
Hart, G.C. 153, 2062
Hartman, W.J. 909
Hartmann, A.J. 843
Hartzman, M. 1149
Hasegawa, T. 1695
Hashimoto, P.S. 893
Hashimoto, T. 134
Haslebach, C.A. 1570
Haspel, R.A. 1854
Hassab, J.C. 2003
Hasselfeld, D.E. 699
Hasselman, T.K. 748, 1425
Hassenpflug, H.L. 2050
Hassett, R. 2198
Hatlestad, B. 706
Hattori, S. 1072
Haug, E.J. 2680
Hauser, G. 2658
Hauser, W.P. 2046
Hausknecht, D.F. 2229
Hausz, F.C. 578
Havens, J.H. 470
Hawkins, N.M. 440
Hayashi, Y. 878, 2323
Hayashikawa, T. 2122
Hayduk, R.J. 751, 930, 1873
Hayek, S.I. 1669
Haymann-Haber, G. 2301
Hays, C.O., Jr. 2044
Hazell, C.R. 2156
Healey, J.J. 239
Heap, N.W. 2000
Heath, W.G. 1440

Heckl, M. 610, 2535
Hedrick, J.K. 1435, 2497, 2498
Heiberger, D. 5
Heifetz, J. 2172
Heilker, W.J. 2412
Heimann, B. 1634
Heining, W. 914
Heinrich, J.C. 2030
Heinzman, J. 498
Hell, T. 682
Hellqvist, K. 2079, 2247, 2248
Hemami, H. 2273
Hemmig, F.G. 929
Henderson, G.R. 1733
Hendricks, S.L. 223
Hendrickson, C. 800
Hengel, M.F. 2074
Hensing, P.C. 872
Hensman, N. 676
Hentschel, W. 1547
Herauld, J.P. 1563
Herbein, W.C. 237
Herbert, M.R. 1129
Herman, A.S. 496
Herman, G.C. 1697
Heron, K.H. 1139
Herrmann, G. 413, 1270
Hertzsch, M. 235
Hess, R.L. 1468, 1573
Hessler, R.O. 1042
Heuschkel, J. 258
Hewitt, J.R. 2580
Heyman, J.S. 432
Heymann, F.J. 128
Heyse, H. 1736
Hickling, R. 2325
Hickman, T.R. 2459
Hickmann, W. 1092
Hieber, G.M. 175
Higashi, K. 2297
Hill, D. 1266
Hill, E. 1326
Hills, S.A. 1088
Hilzinger, J.B. 873, 1175
Hindy, A. 793
Hinton, E. 1135
Hirao, M. 2447
Hirasawa, M. 29
Hirose, T. 1494
Hirschbein, M.S. 1412
Hirschberger, G. 439

Hisa, S.	2582	Hove, D.T.	156	Ianniello, C.	629
Hitchen, I.R.	446	Howard, G.	1835	Ibáñez, P.	1835
Hjorth-Hansen, E.	1191	Howe, M.S.	140, 1968	Iboshi, N.	2344
Ho, Y.S.	318	Howell, A.S.	754	Ibrahim, I.M.	1928
Hoa, S.V.	114	Howell, G.P.	2339	Ibrahim, S.R.	679, 2279
Hoard, R.	2229	Hrovat, D.	2565	Ibrahim, Z.N.	2638
Hobbs, J.	520	Hsieh, B.J.	803	Ichinomiya, O.	1926
Hobson, D.E.	82	Hsieh, R.K.T.	2454	Idczak, W.	2145
Hodges, D.H.	2511	Hsu, C.S.	2262, 2263	Idelsohn, S.	198
Hoenlinger, H.	1619, 1622	Hsu, S.T.	791	Igra, O.	1708
Hoffman, H.	1716	Hsu, T.C.	1251	Iguchi, M.	918, 1828
Hoffmann, A.	267, 736	Hu, A.S.	665	Iida, H.	1168
Hofmann, R.	1359	Hu, C.K.	374	Ikari, H.	1262
Hogge, M.	198	Hu, G.T.	2684, 2685, 2686	Ikeda, T.	1403, 1407
Hohman, J.J.	147	Hu, H.-c.	2022	Ikeuchi, K.	1237
Hollburg, U.	2524	Hu, Y.	2277	Ikui, T.	1295
Holman, G.S.	365	Huang, C.L.	1935	Ilgmann, W.	1878
Holmer, C.I.	128	Huang, H.	362, 2390	Imai, T.	445
Holmes, J.D.	1656	Huang, S.N.	1502	Imezawa, K.	330
Holmes, M.H.	1267	Huang, T.C.	1128, 1344, 1345, 1346, 1347	Inagaki, S.	393
Holmes, P.	1062, 1551	Huber, P.W.	2481	Inagawa, M.	1844
Holmes, P.J.	1328	Hudson, J.H.	497	Ingard, K.U.	1511
Holmes, R.	213, 487, 584, 871, 2633	Hudspeth, R.T.	838, 2072	Inger, G.R.	1323
Holt, J.	1342	Huey, D.C.	2652	Inman, D.J.	1376, 2208
Holzlohner, U.	252	Hughes, P.C.	461	Ino, T.	2533
Honda, Y.	2332	Hughes, R.	2459	Irie, T.	92, 337, 358, 768, 1261, 1262, 1917, 2143, 2393
Honlinger, H.	1459	Hughes, T.J.R.	469, 1134	Irretier, H.	1931
Hooker, R.J.	309, 1725	Huguenin, H.	169	Irving, H.M.	883
Hoover, J.	598	Hugus, G.D., III	1722	Irwin, A.W.	2349
Hoover, W.R.	2045	Huissoon, J.P.	1178	Isakower, R.I.	857
Hopkins, D.M.	1339	Hulbert, G.	2614	Isenberg, J.	852
Hopkins, G.R.	790	Humar, J.	2392	Ishida, K.	328, 329
Horak, D.	1434, 1435	Hundal, M.S.	214, 1565, 2095	Ishida, Y.	1403, 1407
Hori, K.	2447	Hung, N.X.	1282	Ishiguro, N.	495
Hori, Y.	588, 2570	Hunt, D.L.	1104	Ishihara, A.	878
Horikoshi, C.	1075	Huntley, I.D.	135	Ishizaki, T.	361
Horn, A.	1847	Hurst, C.J.	1035	Ishizawa, K.	2297
Horner, G.C.	1875	Huseyin, K.	1395, 2479	Isom, L.E.	1537
Horonjeff, R.	1972	Huston, R.L.	840, 1060, 1491	Isono, H.	958
Horowitz, R.	1548	Hustrulid, W.A.	254	Israeli, M.	2255
Horsager, B.K.	18	Hutchins, C.M.	2648	Issid, N.T.	2130, 2131
Hortel, M.	2302	Hutchinson, J.R.	2132	Issler, L.	369
Horvay, G.	120, 121	Huttelmaier, H.P.	246	Ito, M.	495
Hoshiro, T.	321, 2305	Hutton, P.H.	444, 1751, 2475	Ito, Y.M.	2286
Hothersall, D.C.	2073	Hwang, C.	465, 1458, 2357, 2485	Itoh, A.	359
Hoto, H.	1649	Hwang, R.-Y.	2485	Itou, S.	1383, 2223
Hotz, E.R.	2085	Hyer, M.W.	967		
Houjohn, H.	330				
Housner, G.W.	782				
Housner, J.M.	1626				

Karnopp, D.	1755	Kenworthy, M.	34	Klumpers, K.J.	2105
Karpel, M.	1452	Keowen, R.S.	1363	Knauer, H.S.	149
Kascak, A.F.	222	Keresztes, A.	916	Knisely, C.W.	1327
Kasai, K.	2564	Kerle, H.	1558	Knobelock, J.	2322
Kassawara, R.P.	734	Kerschen, E.J.	1952, 2047, 2420	Knott, P.R.	1859
Kasser, J.	1111	Kerstens, J.G.M.	2483	Knox, K.J.	2544
Kasuba, R.	2372	Keskar, D.A.	1221	Knudson, H.T.	537
Katayama, K.	1059	Kessler, F.M.	2182	Ko, P.L.	133
Katayama, T.	1059	Khalil, T.B.	2091	Ko, S.-H.	944, 2151, 2422
Kathiresan, K.	836	Khan, M.A.	1750	Kobatake, K.	134
Kato, K.	2344	Khandelwal, R.S.	1946	Kobayashi, A.	2615
Kato, T.	2570	Khatib-Rahbar, M.	1833	Kobayashi, A.S.	440, 1284, 1285, 1372, 2616
Katsaitis, S.	1658, 2399	Khorunghin, V.S.	1655	Kobayashi, S.	870
Katto, Y.	1689	Khot, N.S.	1454	Kobler, V.P.	574, 757
Katzenmeier, G.	369	Khurana, O.P.	1734	Kodama, Y.	226
Kauffman, W.M.	536	Kidd, C.C.	1353	Koelle, U.	1634
Kaul, M.	1706	Kidoguchi, H.	1362	Koenigsmann, W.	2373
Kaul, R.K.	86, 413, 1664	Kiefer, R.J.	448	Koga, K.	958
Kausel, E.	884	Kielb, R.E.	110, 1889	Koh, A.-S.	1831
Kavolëlis, A.-P.	494, 593, 594, 595, 651, 652	Kienappel, K.	1709	Kohata, H.	2136
Kawabata, N.	2365	Kienholz, D.A.	390, 2126	Kohler, F.	1244
Kawakami, M.	261	Kientzy, D.W.	1129	Koike, T.	798
Kawanobe, O.	775	Kiessling, F.	1803	Koishikawa, A.	134
Kawata, E.	29	Kikuch, K.	1168	Koizumi, T.	654
Kaye, M.C.	1207	Kikuchi, K.	870, 2533	Kolerus, J.	1109, 1110
Kaynia, A.M.	884, 2561	Kikuchi, M.	1750	Kolitsch, J.	185
Kaza, K.R.V.	312, 1889	Kim, C.E.	2500	Kollegger, J.P.	1921
Kedzior, C.T.	188	Kim, C.H.	2334	Koltzsch, P.	314
Keer, L.M.	388	Kimball, C.E.	1516	Komatsu, K.	2533
Kehl, K.	1803	Kimura, K.	1058, 2205	Konami, S.	1485
Keim, W.	1803	Kinh, N.V.	1998	Kondo, H.	1275
Kelleher, B.J.	1632	Kinoshita, Y.	2417	Kondrat, A.	957
Kellenberger, W.	2506	Kinra, R.K.	1837	Kon-no, A.	412, 414
Keller, A.C.	677	Kiremidjian, A.S.	804	Konstantinidis, S.	262
Kelly, B.E.	2116	Kirk, C.L.	271	Konuk, I.	896
Kelly, J.J.	2173	Kirk, R.G.	523, 1644, 2596	Koopmann, G.H.	1030, 1174
Kelly, J.M.	32, 1142, 2097, 2098	Kirkham, W.R.	47	Koori, Y.	29
Kelly, S.G.	1053	Kirkhope, J.	994	Kopp, J.W.	641, 642
Kempe, G.	289	Kirsch, P.A.	2355	Koppe, R.	1706
Kempner, L., Jr.	534	Kistler, B.L.	1284	Kopriva, Z.	1764
Kempton, A.	1581	Kiureghian, A.D.	821, 799, 1712	Korb, J.	1852
Kennedy, D.A.	2654	Kivity, Y.	2255	Korkosz, G.J.	2253
Kennedy, J.B.	1934	Kiyono, S.	762, 1648	Korn, J.	1753
Kennedy, M.	85	Kleckner, R.J.	204	Kos, M.	1647
Kennedy, R.P.	28, 260	Klein, R.H.	1232	Košábek, J.	249
Kennedy, W.	1178	Klepper, D.L.	245	Kosinski, W.	1321
Kennedy, W.C.	1418, 1470, 1512	Kliem, W.	2477	Kossa, S.S.	2634
Kenny, R.A.	165, 1524	Klimov, D.M.	2568	Kot, C.A.	801, 803
Keowen, R.	1835	Klingenberg, R.	1885	Kotera, T.	219, 452, 1173
Kenttala, J.	60	Klinger, F.	438	Kounadis, A.N.	1248, 1526
		Klompas, N.	2363		

Kovac, J.	1469	Kussmann, A.	949	Lawrence, G.J.L.	2418
Kovac, J.G.	538	Kuttler, J.R.	1263	Lawson, P.	622
Koval, L.R.	1015, 1016	Kuttruff, K.H.	2429	Lazopoulos, C.A.	1692
Kovats, Z.	66, 759	Kwak, Y.K.	276	Lazzeri, L.	1393
Koyama, T.	321, 2305	Kwok, K.C.S.	1824	Lea, J.A.	1501
Kozluk, M.J.	367	Kyomen, S.	1496	Leadbetter, S.A.	566
Kragh, J.	1974			Leader, M.E.	493, 1406
Krajcinovic, D.	2225			Leandre, J.	151
Krämer, E.	1804, 2052, 2527			Lee, C.S.	581
Kramer, K.	220			Lee, G.F.	1528
Krasnicki, E.J.	657, 2209			Lee, J.	1318
Krause, H.	2099			Lee, J.K.	2361
Krauss, A.	289			Lee, L.H.N.	366, 368, 796, 1665, 1761, 2455
Krauter, A.I.	2574			Lee, M.Z.	379
Krenevičius, A.	599			Lee, S.Y.	2084
Krenk, S.	2400			Lee, T.H.	22
Kress, R.	1562			Lee, T.W.	854
Kretschy, M.	317			Lee, W.H.	755
Krieg, R.	263, 1939, 1943, 2165			Lees, A.W.	2586
Krinsky, S.	1483			Lehmann, D.	1886
Krishna, R.	296			Lehringer, F.J.	621
Krishnan, V.	1461			Leie, B.	489
Kristiansen, U.R.	1050, 2362			Leipholz, H.H.	2310
Krodkiemski, T.	501			Leis, B.N.	2519
Krodkiemski, J.	2515			Leissa, A.W.	100, 101, 617, 865, 1259, 2158, 2361, 2612
Krousgrill, C.M., Jr.	1691			LeMay, I.	834
Krulick, T.G.	2689			Lena, A.L.	2468
Krumm, H.	876			Leon, R.L.	189
Kryter, R.C.	802			Leonard, J.W.	838, 2072, 2380
Kubo, A.	762			Leonavičius, M.-K.	599, 600
Kuehn, M.	1622			Leoni, R.D.	1227
Kuemmerle, W.	1583			Leontaritis, I.	1775
Kufert, D.	800			Lepelletier, T.G.	2314
Kuhn, M.	1459			Lepik, Ü.	1900
Kuhl, W.	613			Lepor, M.	1449
Kulak, R.F.	2673			Lerchbacker, A.B.	434
Kulkarni, S.V.	2103			Lesueur, C.	104, 108
Kumar, B.	833			Leu, M.C.	1479
Kumar, R.	2161			Leung, A.Y.-T.	1379
Kundert, W.R.	1732			Leung, Y.T.	1136, 1914
Kunow-Baumhauer, A.	1004			Levek, R.	1147
Kunzel, V.	1184			Levek, R.J.	1224
Kuo, C.-P.	2678			Leventhall, H.G.	1231, 2174
Kurajian, G.M.	164, 1564			Levin, H.A.	891
Kurakake, Y.	298			Levine, H.S.	2081
Kurkov, A.P.	2360			Levine, N.	1876
Kurra, S.	633			Levinson, M.	997, 1899
Kurtz, R.J.	444, 2475			Levshin, A.L.	389
Kurz, K.	1842			Levy, B.S.	2352
Kushner, A.S.	2254				
Kushner, F.	224, 670				

L

Mallikarjunarao, C.	33	Mathews, F.H.	2245, 2246	Merced, V.S.	1411
Mallory, W.R.	1537	Mathewson, K.J.R.	65	Mercer, F.T.	1728
Manfrida, G.	760	Mathiassen, S.	1912	Meredith, D.	2125
Mangiarotty, R.A.	2337	Mathieson, T.A.	188	Merker, H.J.	2104
Manner, A.	37, 928	Matsuda, T.	328, 329	Merriman, T.	1108
Manolescu, N.I.	2272	Matsuhisa, H.	2332	Merritt, P.	287
Manolis, G.D.	2024	Matsumoto, H.	338, 355, 359,	Merritt, P.H.	556, 668
Manolis, G.M.	2065		1680	Mertens, H.	570
Mansouri, T.A.	733	Matsuo, H.	1853	Messall, J.F.	692
Marcotte, P.P.	65	Matsuo, K.	1295, 1853	Messing, W.	2250
Marczak, J.	2187	Matsushita, O.	870, 2533	Mettler, E.	2436
Maresca, C.	1624	Matsuura, T.	2582	Metzger, W.W.	2089
Margolis, D.L.	462, 841, 1380,	Matsuzaki, Y.	2146	Meyer, G.	187
	2565	Matsuzawa, K.	1695	Meyer, K.J.	1821
Margulies, G.	421	Maurer, J.K.	1185	Meyer, W.	1611
Mariamy, Y.A.	2598	Mayes, I.W.	2520	Meyer, W.L.	1505
Maričić, N.L.	752	Maxwell, D.E.	2540	Miao, W.	284
Markert, R.	491, 1807	Maxwell, J.H.	1360	Michelberger, P.	916
Marks, W.L.	1987	Maxwell, T.L.	2411	Midha, A.	1489, 2296, 2378
Markuš, Š.	341, 1250, 1783, 2395	May, D.N.	807, 808, 809, 810,	Mielcarek, A.	1849
Marley, S.J.	577		811	Mikulcik, E.C.	742
Maroney, G.E.	546	Mayes, R.L.	2309	Miles, J.H.	2423
Marsh, H.	589	Mazumdar, J.	1266	Miller, C.A.	195, 1779, 2043,
Marsh, K.J.	2006	Meachum, T.R.	436		2504
Marshall, A.	82	Meacham, W.L.	2292	Miller, D.M.	2394
Marshall, L.G.	245	Mead, D.J.	1725	Miller, J.C.	1232
Marshall, P.W.	1837	Medaglia, J.M.	626	Miller, J.G.	1507
Marshall, R.L.	1035	Medearis, K.	1415	Miller, L.G.	216
Martelli, F.	760	Medwin, H.	1703	Miller, R.E.	343
Martin, D.J.	886	Meeker, D.B.	567	Miller, R.K.	2446
Martin, F.A.	581, 2109	Meggitt, D.J.	2119	Miller, R.N.	835
Martin, H.R.	1501	Mehta, N.C.	2351	Miller, V.R.	2085
Martin, R.M.	1612	Mei, C.	41, 285, 1218	Miller, W.R.	1446
Martin, W.W.	1836	Meinke, P.	1849	Mills, G.R.	1458
Martinek, F.	2217	Meier-Dornberg, K.E.	687	Milsted, M.G.	972
Martinez, P.A.	1363	Meieran, H.B.	258	Mindle, W.L.	970
Martynyuk, A.A.	1377	Meirovitch, L.	1125	Mindlin, R.D.	107
Maruyama, K.	1926	Melbourne, W.H.	1824	Minkenberg, H.L.	1841
Marynowski, K.	501, 2515	Meldrum, B.H.	658	Mirandy, L.	564
Masri, S.F.	2598	Melke, J.	1851	Mirick, P.H.	1585
Marzok, U.	650, 1776	Meller, E.	2080	Mirow, H.J.	2010
Mas, C.	1980	Mellingen, K.	706	Miserentino, R.	566
Masao, T.	29	Meltzer, G.	297, 2353	Mishra, A.K.	590
Maslen, K.R.	1531	Melvin, J.W.	1573	Miskevics, A.J.	1077
Mason, D.R.	561, 562	Melzig-Thiel, R.	297, 2353	Misovec, A.P.	2081
Masri, S.F.	1488, 1907, 2387	Mendelsohn, D.A.	388	Mital, N.K.	1653
Massoud, M.	1571, 2358	Mendenhall, M.R.	1567	Mitchel, B.J.	405
Masterson, D.M.	1854	Menge, C.W.	149	Mitchell, L.D.	2493
Matheson, M.J.	1656	Mengi, Y.	1039	Mitchell, J.S.	695, 1748
Mathew, J.	2183	Mengle, V.G.	485	Mitchell, L.D.	856, 1819, 2676
Mathews, D.C.	39	Mente, L.L.	1730	Mitchiner, R.G.	2493

Nelson, R.B. 2286
 Nelson, R.L. 1160
 Nelson, T.A. 891
 Nerz, K.P. 1111
 Nesbit, E.E. 694
 Neubert, V.H. . . . 767, 2092, 2599
 Neuerburg, W. . . . 1593, 1999, 2538
 Neumann, R. 648
 Neuts, M.F. 1520
 New, R.W. 231
 Newman, J.C., Jr. . . . 1994
 Newmark, N.M. 16
 Newton, R.E. 471
 Nezu, K. 1362
 Ng, K.W. 1487
 Nhuan, P.D. 10
 Ni, C.M. 2354
 Niblett, L.T. 1663
 Niblett, T. 1247
 Nicholas, J.C. 315, 523, 586,
 1644, 2596
 Nicholson, D.W. 2196
 Nickerson, D.B. 473
 Nicolae, V. 431
 Nielsen, H.B. 2517
 Nigam, N.C. 1946
 Nigh, G.L. 2512
 Nigul, U. 1552
 Nijs, L. 1206
 Nikiforuk, P.N. 1333
 Nikolajsen, J.L. 871
 Nilrat, F. 1711
 Nilsson, A.C. 116
 Nintzel, A.J. 690
 Nishi, S. 2179
 Nishikawa, T. 720
 Nishimura, T. 403
 Nishioka, T. . . . 459, 460, 539, 1130,
 1131, 1132, 2637
 Nishitani, A. 826
 Nishiyama, T. 2364
 Nisonger, R.L. 33
 Nissim, E. 2035, 2556
 Niyogi, B.K. 26
 Noah, S.T. 790, 2391
 Nocilla, S. 1770
 Noll, T.E. 1458
 Nollau, R. 232
 Nomoto, H. 1689
 Nonami, K. 1170, 1404
 Noonan, E.F. 2288

Noor, A.K. 2265, 2283
 Noordzij, L. 2333
 Nordell, W.J. 2119
 Nordenson, G.J.P. 17
 Nordmann, R. 316, 2583
 Norris, A.N. 2473
 Norris, T.R. 1472
 Norton, M.P. 2416
 Norwood, C.J. 91
 Novak, M. 732, 793
 Novomestky, F. 1144
 Numrich, S.K. 1702
 Nystrom, P.A. 311

O

Oates, J.B. 2164
 Obernhuber, P. 400
 Oblizajek, K.L. 2359
 Ochi, M. 1695
 Ochiai, S. 29
 Oda, S. 327, 2367
 O'Donnell, M. 1507
 Oesterle, R.G. 384
 Oey, K.T. 404
 Oftedal, G. 50
 Ogendo, J.E.W. 972
 Ogimoto, K. 381
 Ohanehi, D.C. 1419
 O'Hare, J.E. 1090
 Ohashi, H. 488
 Ohlrich, M. 923
 Ohmi, M. 1496
 Ohnishi, K. 1832
 Ohrstrom, E. 52
 Ohshio, Y. 1832
 Ohya, A. 1253
 Oie, S. 145
 Okabe, S. 2061
 Okajima, M. 29
 Okamoto, S. 1494
 Okamoto, Y. 355
 Okazaki, T. 1680
 O'Keefe, E.J. 14
 O'Keefe, J.V. 2337
 O'Keefe, J.M. 2651
 Okumura, M. 261
 Oldham, D.J. 13, 2000
 Oledzki, A. 10, 2216

Oliferuk, W. 1235
 Oliva, M.G. 2135
 Oliver, M.J. 1088
 Olivieri, M. 1823
 Olsen, J.J. 286
 Olson, D. 787
 Olson, M.D. 2512
 Oltmann, R. 2278
 O'Massey, R.C. 1462
 Omata, S. 177
 On, F. 564
 Ono, K. 442
 Ono, T. 720, 1096
 Ookuma, M. 2463
 Opilski, A. 1977
 Oppenheim, I. 800
 Oppenheim, I.J. 1821
 Orey, S. 1550
 Ormerod, M. 288
 O'Rourke, M.J. 255
 O'Rourke, T.D. 797, 2419
 Orsi, A.P. 230
 Osborn, J. 915
 Osman, M.M. 807, 808, 809
 Ostrem, F.E. 635
 Ostrowski, P.P. 1519, 1981
 Ota, H. 721, 2295, 2521
 Otomo, K. 966
 Otsuki, Y. 1253
 Ottens, H.H. 1079
 Ottl, D. 2207
 Ousset, Y. 2028
 Oviatt, M.D. 2534
 Owsik, J. 2187
 Özgüven, H.N. 1923

P

Paddy, R.H. 2320
 Padgaonkar, A.J. 2329
 Padovan, J. 8, 221, 1330, 1801,
 1984, 2682, 2683
 Padula, S.L. 774, 1864
 Paez, T.L. 686, 2249
 Page, J. 1820
 Pagliarini, G. 1013
 Páidoussis, M.P. . . . 2130, 2131, 2413,
 2415
 Pajewski, W. 1998

Pal, N.	376, 792	Peeken, H.	1240, 1650, 1815,	Pirvics, J.	80, 204
Palladino, J.	1580	Peigney, J.	2525	Pisano, A.D.	705
Palmov, V.A.	1122	Peirce, S.	722	Pisarski, J.J.	525
Pan, C.H.T.	75, 315, 1892, 1893	Pekau, O.A.	2326	Pissarev, A.	2293
Pancholy, M.	2014	Pelton, H.K.	246, 2189	Pister, K.S.	2176
Pandey, P.C.	2586	Pentek, W.	816	Pizzirusso, J.	942
Pandey, R.C.	2296	Penzien, J.	1741	Platzer, M.F.	2201
Pandit, M.	2461	Peppler, R.D.	773	Plaut, R.H.	976, 2137
Panek, C.	2200	Perdikaris, P.C.	2350	Ploch, J.	1762
Panik, F.	1846	Peri, M.	27	Plumlee, H.E., Jr.	170, 1615
Panteliou, S.	1171	Perl, M.	1382, 2637	Pocock, R.G.	2418
Pao, J.-H.	2181	Perla, H.F.	90, 1285, 2615	Pokallus, R.	439, 2464
Pao, Y.-H.	2402, 2403, 2404,	Pernet, D.F.	260	Pokorski, J.	305
.	2443	Persicke, G.	1857	Polentz, L.M.	575
Papadrakakis, M.	1119	Persoon, A.J.	905	Polhemus, N.W.	2674
Papastavridis, J.G.	2027	Peško, F.	881	Polidorou, G.	749
Paplinski, A.	2191	Peters, D.A.	710	Politch, J.	2647
Pappa, R.S.	2279	Peters, R.B.	2516	Pollack, M.L.	391, 1499, 1513
Pappas, M.	1141	Peterson, D.	668	Pollard, H.F.	1030
Parameswaran, K.	1492	Peterson, E.C.	785	Pompoli, R.	1013, 1196
Pardee, W.J.	2448	Petrie, A.M.	2322	Ponter, A.R.S.	166
Park, K.C.	712, 1626, 2271	Pettigrew, M.J.	135	Pook, L.P.	2641
Park, Y.J.	2441	Petulli, G.	133	Pope, J.	2325
Park, Y.-S.	1723	Petyt, M.	2376	Pope, L.D.	779
Parker, G.A.	463	Peyrot, A.H.	1010, 1068	Pope, R.J.	1100
Parker, J.V.	892	Pfaffinger, D.D.	766	Popelar, C.H.	119, 401, 662, 2629
Parkins, D.W.	1713, 1714, 2108	Philippacopoulos, A.J.	2284	Popolo, J.	2464
Parkinson, A.G.	700, 2474, 2661	Phillips, G.J.	30, 154	Popolo, J.J.	439
Parnes, R.	1503, 1983	Phillips, C.	176	Popov, E.P.	2178
Parr, V.B.	646	Phillips, J.W.	920	Popov, R.V.	1557
Parrish, B.	1371	Phipps, M.A.	374	Popp, K.	550, 1073, 1120
Parszewski, Z.	501, 2515	Pi, W.S.	676	Porat, I.	832, 1904
Pasic, H.	1270	Pianko, M.	2357	Port, K.F.	1006
Paskin, A.	1322	Pickup, N.	282	Porter, C.S.	1597
Pasquinelli, G.	398	Pielert, J.H.	2337	Porter, M.L.	1038
Passannanti, A.	1182	Piersol, A.G.	1399	Potter, R.E.	1854
Passerello, C.E.	840	Pietruszka, W.D.	936, 1213	Potter, S.	2299
Patching, C.A.	1085	Pifko, A.B.	1814	Pouyet, J.M.	1800
Patel, B.L.	763	Pih, H.	46, 2190	Powell, C.A.	935
Patra, M.K.	998	Pilkey, W.	2016	Powell, G.H.	2177
Patrick, R.P.	1316	Pilkey, W.D.	1543	Pozzi, M.	551, 899
Patterson, C.	2588	Pillasch, D.W.	2048	Prabhu, P.	1080
Paul, D.K.	1135	Pilz, H.	1269	Prasad, B.	1659
Paul, H.S.	1965	Pinazzi, F.	232	Prasad, M.G.	63
Paul, R.	1734	Pinkus, O.	38	Prasad, P.	2329
Paul, W.	1208	Pinnkamp, W.	2106	Prathap, G.	969, 1492, 2382
Pavelic, V.	2490	Pinnington, R.J.	324	Pratt, H.R.	254
Pawlowska, V.	853	Pinson, L.D.	2096	Pratt, T.K.	1986
Payne, B.W.	288	Pinzauti, M.	566	Preisser, J.S.	753
Payne, J.B.	467	Piotrowski, J.D.	2508	Preuss, R.D.	714
Payne, S.G.	713	. . . . .	708	Price, W.G.	925, 927

Pritz, T. 1071, 2597
 Proepper, U. 2651
 Prössler, E.-K. 2281
 Pujara, K.K. 350
 Puch, A. 2290
 Pupeikis, R. 595
 Purcell, W.E. 55, 2624
 Putman, W.F. 183
 Pyke, R.M. 2540

Q

Quinones, D.F. 2285
 Quittner, E. 557

R

Raab, A. 227
 Racca, R. 2562
 Radcliffe, C.J. 1258
 Radcliffe, W.J. 1799
 Rader, D. 480
 Radnoti, G. 2252
 Radhakrishnan, T. 2476
 Ræ, J.M. 622
 Raffie, S. 2449
 Ragland, C.L., Jr. 2328
 Rainey, J.T. 670
 Raju, D.P. 1965
 Raju, P.K. 148, 2650
 RamaChandran, P.V. 1850
 Ramaiah, G.K. 111, 1001
 Ramakrishnan, C.V. 2377
 Ramamurti, V. 99, 353, 1002,
 2148, 2294
 Raman, A. 4
 Raman, P.V. 987, 1260
 Ramaswamy, S. 1118
 Ramamurti, V. 2307
 Ramchandani, M. 791
 Ramulu, M. 1372
 Ranatza, S. 543
 Rand, D. 1551
 Rand, R.H. 406, 1328
 Randall, K.E. 1880
 Randall, R.B. 2657
 Raney, J.P. 932, 1212, 1864

Rangacharyulu, M.A.V. 1874
 Rangaiah, V.P. 767, 2599
 Rangarajan, A. 1639
 Ranta, D.E. 2254
 Rao, A.C. 1556, 1654
 Rao, B.V.A. 980, 2141
 Rao, C.R.A. 2487
 Rao, D.K. 1162, 2510
 Rao, G.V. 1545
 Rao, J.S. 256, 2103, 2510
 Raous, M. 2029
 Raspet, R. 812
 Ratwani, M.M. 2439
 Raty, K. 60
 Rau, G. 1704
 Ray, A.G. 2670
 Ray, H. 1280
 Rdzanek, W. 1930
 Rebont, J.M. 1624
 Rebora, B. 2168
 Reddy, A.S.S.R. 296
 Reddy, C.V.R. 980, 2141
 Reddy, J.N. 776, 1929, 1935,
 1937, 2149, 2386, 2604
 Reddy, V.S. 776, 2604
 Redfern, J.T. 173
 Reding, J.P. 1210
 Reed, J.W. 28
 Reed, W. 1621
 Reed, W.E. 482, 483
 Reese, J.M. 2437
 Reethof, G. 781, 1486, 1497
 Rega, G. 84, 820, 963
 Reich, M. 1149
 Reid, J.G. 850
 Reinicke, W.L. 19
 Reissland, M.-U. 2078
 Reistad, K. 301
 Rejf, P. 262
 Reneker, D.H. 2012
 Rentz, P. 1835
 Rentz, P.E. 2342
 Rericha, I. 1209
 Reshotko, M. 1451
 Retelle, J.P., Jr. 2654
 Rezansoff, T. 2589
 Ribbens, W.B. 2457
 Ricciardiello, L. 38
 Richard, J. 273, 1249
 Richards, E.J. 2184
 Richardson, J. 2198

Richter, J. 1514
 Ricketts, R.A. 1620
 Ricketts, R.H. 1456
 Rickley, E.J. 1443
 Riedel, E.P. 19
 Riegel, J.P., III 643
 Rieger, N.F. 2675
 Rienstra, S.W. 1500
 Riffel, R.E. 727
 Riganti, R. 419, 1121
 Rimrott, F.P.J. 1902
 Rippl, A. 1803
 Risitano, A. 339
 Rivard, A. 2642
 Rivin, E.I. 1417
 Rizk, M.N.F. 1928
 Robb, D.A. 999
 Roberts, C.C., Jr. 505
 Roberts, J.B. 1066, 1782, 1985,
 2033, 2335
 Roberts, W.B. 875
 Robertson, J. 1469
 Robinson, D.W. 1633
 Robson, J.D. 160, 2206, 2630
 Rockwell, D. 1286
 Rockwell, T.H. 2007, 2690
 Rodal, J.J.A. 663
 Rodean, H.C. 1517
 Rodriguez, C. 2168
 Roeck, G.P.J.M. 2536
 Roemer, L.E. 1364
 Roemer, R.E. 755, 786
 Roesset, J.M. 468, 885
 Rogers, L. 2212
 Rogers, L.C. 2126
 Rohde, D.F. 2625
 Rohde, S.M. 73, 2577
 Rohn, D.A. 2303, 2304
 Rohrle, H. 1381
 Rojahn, C. 2062
 Rokhlin, S.I. 1701
 Roland, J. 1420, 2175
 Romander, C.M. 541
 Ronen, A. 1482
 Ronen, T. 1220
 Ronneberger, D. 1052
 Rooke, J.H. 869
 Rooker, J.R. 1373
 Röper, R. 1651
 Ropte, E. 1637
 Rosakis, A.J. 2636

Roseau, M.	2435	Saff, C.R.	481	Sathyamoorthy, M.	1671
Rosenau, W.	277	Safford, F.B.	688, 2243	Sato, H.	968
Roskam, J.	1034, 1294	Sagner, M.	373	Sato, K.	445, 2308
Ross, C.A.	598, 619	Sahay, C.	1161	Sato, S.	321, 2305, 2332
Ross, C.F.	1975	Sa'id, W.K.	1884	Sato, T.	1112, 1826
Ross, C.T.F.	1006	Saiidi, M.	882, 1915	Satsangi, K.	754
Ross, D.F.	142	Saikudo, R.	1832	Satter, M.A.	628, 1515
Ross, H.E., Jr.	900, 901	Sailors, R.H.	2635	Sattinger, S.S.	667
Rossini, T.	2573	Saito, H.	775, 2129	Satyanarayana, A.	799
Rossmannith, H.P.	2224	Saito, Y.	654	Satyanarayana, V.V.	256
Rostafinski, W.	1961	Saito-o, M.	1636	Saul, R.A.	2328
Rott, D.	1991	Sakai, H.	1476, 1887	Sawyer, J.	1625
Roufaeil, O.L.	109, 983	Sakamot, H.	2318	Sayed-Esfahani, R.	2240
Round, D.F.	1709	Sakata, M.	1058, 2179, 2205	Sayhi, M.N.	2028
Roure, A.	1048	Sakata, T.	1922	Sayir, M.	340
Rowbottom, M.D.	2213	Salah el din, A.S.	2644	Sazama, F.J.	2244
Rowell, D.	1427, 1811	Salama, M.	2124	Scala, M.	1393
Roxner, T.	1858	Salamone, D.J.	1409, 1641, 2665	Scalise, D.T.	1279
Rozelle, D.M.	2486	Salane, H.J.	1908	Scarton, H.A.	1418, 1470, 1512
Rubek, J.	266	Salewski, K.	650	Scawthorn, C.	1591
Rubin, M.	538	Salewski, K.-D.	1776	Scedel, W.	124
Rubin, M.N.	627	Salikuddin, M.	170	Schachne, G.L.	558
Ruddy, A.V.	507, 587	Salter, R.J.	2073	Schachenmann, A.	1286
Ruge, P.	2496	Salzwedel, H.	1332	Schade, D.	2020
Ruhl, J.A.	1838	Sampat, P.T.	320	Schafer, B.	962, 1245
Ruhlin, C.L.	43	Samson, A.	1769	Schafer, M.	919
Ruijgrok, G.J.J.	1216	Samueli, H.	1535	Schaller, R.J.	1
RuLiang Wang, L.	795	Sancar, S.	2443, 2444	Schänzer, G.	42
Rungta, R.	2519	Sand, I.O.	973	Scharf, L.L.	1138, 2230
Rupprecht, S.	2492	Sandercock, D.M.	875	Scharton, T.D.	1353
Russell, D.L.	1076	Sandler, B.	1183	Schatte, M.	297
Ryan, R.S.	565	Sandman, B.E.	572	Schauble, C.C.	619
Rybicki, R.	1646	Sandstrom, R.E.	1608	Scheelke, I.	2651
Rybicki, R.C.	1177	Sani, G.	38	Scheithe, W.	1996
Ryder, J.T.	1341	Sankar, S.	114, 2058, 2210, 2211	Schiff, A.J.	738, 1777
Rylander, R.	49, 52	Sankar, T.S.	191, 2058, 2140	Schiff, M.I.	1447
Rymarz, CZ.	2145	Sankewitsch, V.	1635	Schilling, U.	1675

S

Saadat, H.	1256	Santana, C.	193, 456	Schmeisser, G.	9
Sachdev, S.S.	557	Santoboni, S.	907	Schmidt, G.	2021, 2302
Sachdeva, T.D.	2377	Sanyal, A.	1162	Schmidt, G.S.	1742
Sachse, W.	2444	Sarfeld, W.	1805	Schmidt, H.	2400
Sackman, J.L.	32, 638, 1142	Sarker, P.K.	1933	Schmidt, J.H.	558, 2231
Sadek, E.A.	450	Sarmiento, G.S.	115, 454, 2025	Schmidt, K.-J.	2239
Sadek, M.M.	880	Sarzynski, A.	2187	Schmidt, W.C.	532
Safak, E.	1964, 2063	Sas, P.	1607	Schmitz, F.H.	1225, 1586
Safar, Z.S.	74	Sasaki, K.	1112	Schneider, J.	2496
		Sasaki, R.	2297	Schneider, R.E.	363
		Sasakura, Y.	2503	Schnenk, E.B.	444
		Sassi, W.V.	1400, 1401, 1402	Schoffler, W.	228

Schofield, C.	1028	Sensburg, O.	938, 1459, 1619,	Shih, Y.	465
Scholl, D.H.	369	.....	1622, 1623	Shih, Y.-P.	2485
Scholl, R.E.	1916	Sentz, R.H.	515	Shilkrot, D.	1684
Schöllhorn, K.	316, 2583	Senuma, T.	2099	Shimizu, M.	261, 545
Schomer, P.D.	1464, 2182	Seppala, S.	37, 928	Shimizu, N.	29
Schott, G.	1718	Serdyuk, V.A.	2640	Shimode, S.	2548
Schrader, K.	307	Sergev, S.S.	1657, 1898	Shimogo, T.	344, 2531
Schrapel, H.-D.	2484	Seshadri, T.V.	2077	Shin, Y.S.	1834
Schreiber, E.	1114	Seshagiri, B.V.	1879	Shinohara, Y.	344
Schreiber, U.	741	Seth, B.	186	Shinozuka, M.	798
Schreyer, H.L.	2628	Sethi, J.S.	26	Shiohata, K.	1115
Schricker, V.	1255, 2177	Sethi, V.S.	1734	Shiohato, K.	445
Schröder, A.	741	Sethna, P.R.	1334, 1550	Shipley, S.A.	1838
Schroter, V.	1918, 1920	Severud, L.K.	1502	Shirakawa, K.	1405, 1668
Schuetz, D.	1991	Sewall, J.L.	2088	Shirasawa, H.	2375
Schulze, H.	2550	Sexton, J.S.	531	Shirey, D.L.	644, 2245
Schuman, W.J., Jr.	2243	Sexton, M.R.	948	Shivashankara, B.N.	1155, 1390,
Schumann, U.	375, 544, 1602	Seybert, A.F.	1690, 2215, 2228	.....	1613
Schutz, D.	1617	Seznec, R.	1308	Shoji, H.	488
Schutzenhofer, L.A.	565	Shah, A.H.	1498	Sholping, S.	371
Schwabe, J.E.	785	Shah, V.N.	843, 1825	Shoyama, E.	445
Schwager, K.W.	1444	Shaker, B.S.	1064	Shrivastava, S.K.	2480
Schwanecke, H.	70	Shanbhag, R.L.	2602	Shukla, K.N.	2414
Schwartz, E.	570	Shanker, A.	1653	Shuman, R.L.	1358
Schwarz, H.R.	2495	Sharan, A.M.	2058	Shupert, P.T.	537
Schweitzer, G.	2572	Shapiro, W.	79	Shurui, Z.	386
Schwenzfeier, W.	2458	Sharma, C.B.	1011	Shuttleworth, R.	1724
Schwerdlin, H.	332, 1243	Sharma, J.K.N.	1179	Siddiqui, F.	2120
Schwieger, E.	2002	Sharma, M.G.	2449	Siekman, J.	1675
Schwieger, H.	611	Sharp, R.S.	701, 1205	Sierakowski, R.L.	152, 598
Scott, J.	564	Sharpe, R.L.	2309	Sievert, W.	693
Scott, J.N.	573	Shatalov, L.N.	2663, 2669	Sigillito, V.G.	113
Scott, R.A.	1086	Shatoff, H.D.	22	Sigbjornsson, R.	728, 1191
Scott, R.F.	1596	Shaw, L.L.	2084	Sigillito, V.G.	1263
Scott, W.E.	411	Shaw, R.P.	86, 996, 1664	Silva, G.	1896
Sears, J.A.	567	Shawki, G.S.A.	74	Silva, J.M.M.	554
Segal, Y.	1012	Shea, R.	692	Silver, W.	2289
Segall, A.	97	Sheinman, I.	609	Silvia, M.T.	1300, 1301
Segel, L.	1845	Shen, S.F.	485	Šimčák, F.	451
Seguchi, Y.	1145	Shen, Y.-p.	2023	Šimiú, E.	2425
Seidman, H.	1392	Shepherd, R.	2601	Šimková, O.	341, 1250
Seireg, A.	58, 2093	Sher, L.	287	Simmonds, J.G.	2401
Schwieger, E.	2460	Sheth, P.N.	537, 577	Simmons, H.R.	517
Seireg, A.	2370	Shibata, T.	321	Simmons, J.M.	2201
Sekhar Reddy, B.	117	Shibata, Y.	1075	Simmons, P.E.	2529
Sekiguchi, H.	1096	Shieh, G.P.	1438	Simon, S.	1938, 2438
Sekino, H.	338	Shield, B.M.	1391	Simonian, S.S.	1425, 1773, 1774
Sekiya, T.	1059	Shih, C.-F.	784	Simonis, J.C.	129
Selvadurai, A.P.S.	1936	Shih, T.	772	Simpson, A.	924
Seneny, P.E.	1421	Shih, T.-Y.	2194	Simpson, J.M.	47

Sinai, Y.L.	2421	Sobieczky, H.	1323	Stangl, G.	1432
Singer, J.	1012	Sobieraj, W.	2102	Stanisic, M.M.	1553
Singh, H.	805	Sobol, T.	2428	Stanway, R.	2240
Singh, I.R.	1935, 2386	Soderman, P.T.	2563	Starsmore, N.	895
Singh, M.	743	Soeda, T.	2471	Stathis, T.C.	1233
Singh, M.P.	825	Soedel, W.	63	Stavsky, Y.	2407
Singh, Y.P.	1329	Soenarko, B.	1690	Stecco, S.S.	2508
Singhal, K.	1771	Sofrin, T.G.	39	Stecki, J.S.	1587
Singley, G.T., III.	1223	Solecki, R.	351	Steele, C.M.	815
Siorek, R.W.	1473	Sollmann, H.	1577	Steele, C.R.	2270
Šipoš, L.	2366	Solo, V.	711	Steele, G.H.	1103
Sires-Yifat, C.	1835	Somers, C.	2645	Steele, J.M.	2675
Siskind, D.E.	641, 642, 2008	Someya, T.	2582	Stefanini, A.	1546
Sitarek, I.	1235	Sommerschuh, St.	9	Stehlin, P.	472, 1156
Sivák, B.	2366	Sone, T.	1973	Stenander, L.R.	2659
Sivák, J.A.	183	Soni, M.L.	2219	Stepanishen, P.	349
Sivák, M.	2366	Sonin, A.A.	2257	Stephanakis, K.	1563
Skaar, K.T.	750	Sonnenburg, P.N.	576	Stephen, N.G.	964
Skelton, R.E.	461	Sonon, D.E.	64	Stephenson, D.F.	254
Skingle, C.W.	1139	Soom, A.	1501	Stephenson, R.A.	1134
Skinner, M.S.	2097, 2098	Soong, T.T.	830	Sternberg, A.	978
Skop, R.A.	2180	Soovere, J.	680	Stetson, K.A.	855
Skorpik, J.R.	1751	Sorensen, A., Jr.	1475	Stevens, D.G.	571
Skrikerud, P.E.	242, 251	Sorensen, J.P.	202	Stevens, J.A.	363
Skulte, P.	2519	Sorensen, S.	49	Stevens, K.K.	1070
Slazak, M.	98	Southern, I.S.	1812	Stevenson, J.D.	542
Sleeper, R.K.	308	Southgate, H.F.	470	Stewart, D.R.	14
Slocombe, M.D.	2507	Sozen, M.A.	1915	Stewart, N.D.	813
Smalley, A.J.	656, 700, 2474, 2661	Spada, A.J.	789	Stewart, R.M.	1747, 2671
Smallwood, D.O.	2197, 683	Spagnolo, R.	2005	Stewart, W.E.	202
Smeulders, J.P.M.	1687	Spanos, P.-T.D.	280, 898, 1760, 2276	Stoessel, J.	1835
Smith, C.	1835	Sparks, C.P.	897	Stone, B.J.	531, 1239, 2571
Smith, C.C.	276	Spath, W.	1298	Stone, D.H.	2441
Smith, D.M.	2505	Spencer, A.C.	269	Stone, J.R.	1861
Smith, D.R.	517	Spierings, P.T.J.	1848	Stoneking, J.E.	802
Smith, G.C.C.	2037, 2041	Springer, H.	1890	Storment, J.W.	816
Smith, I.J.	729	Spruogis, B.	651, 652	Stott, S.J.	1488
Smith, I.M.	655	Spychala, A.	2145	Strang, J.M.	2319
Smith, J.D.	2251	Sreenivasamurthy, S.	2294	Straub, F.K.	1463
Smith, J.R.	1545	Srinivasan, A.V.	950	Stredulinsky, D.C.	634
Smith, L.G.	2236	Srinivasan, M.G.	2225	Streich, M.	650
Smith, P.W., Jr.	200, 981, 1988	Srinivasan, S.	1734	Strelcyn, J.	844, 845
Smith, R.L.	835	Srinivasan, V.	99, 353, 1002, 2148, 2307	Strickland, W.S.	598
Smith, S.	534, 1106	Stachura, V.J.	642, 2008	Strickle, E.	1637
Smith, T.	622	Stafford, J.R.	2166	Strike, W.T.	1090
Smolka, S.A.	714	Stagg, M.S.	640, 641, 642	Stroud, R.C.	534, 1106
Sneck, H.J.	1883	Stahle, C.V.	559	Strumpf, H.	1895
Snoeys, R.	1481, 1607	Stammers, C.W.	1025	Stuart, R.J.	612
Snyder, W.T.	1054	Stange, W.A.	1091	Stühler, W.	1802, 1894
Soavi, F.	756			Stussi, U.W.	2409
				Su, T.C.	1945, 1949, 2613

Suarez, J.J.	877	Takahara, S.	96, 2617	Theuerkauf, J.P.	1473
Subrahmanyam, K.B.	2103	Takahashi, H.	1750	Thien, M.D.	2358
Succi, G.P.	931	Takahashi, I.	92, 337, 768	Thomas, D.W.	2472
Sugihara, K.	2323	Takahashi, S.	1268	Thomas, G.B.	2523
Sugimoto, N.	1272, 2605, 2606	Takamatsu, Y.	226	Thomas, H.J.	489
Sullivan, T.D.	56	Takatsu, H.	261	Thomas, T.J.	1561
Sullivan, W.N.	1578	Takasaki, Y.	29	Thomasson, S.I.	138
Summers-Smith, D.	507	Takatsu, H.	545	Thompkins, W.T., Jr.	2301
Sunada, W.	2590	Takatsu, N.	2308	Thompson, A.G.	54
Sundara Raja Iyengar, K.T.	987	Takeda, K.	1433	Thompson, B.S.	1484
Sundararajan, C.	194, 1283, 1385	Takeda, N.	152	Thompson, D.E.	2051
Sundararajan, V.	2391	Takeda, Y.	358	Thompson, H.J.	1089
Sung, L.	1070	Takeuchi, K.	269	Thompson, I.	1969
Sung, S.H.	2321	Takeuchi, R.	145, 2147	Thompson, J.K.	2227
Sussman, N.E.	207	Takeuti, Y.	2405	Thompson, R.W.	22
Sutcliffe, W.G.	2651	Takezono, S.	126	Thompson, W., Jr.	2437
Suzuki, K.	1268	Tamura, A.	1168, 2522	Thompson, W.E.	653
Suzuki, M.	134, 1750	Tamura, H.	955	Thompson, W.I.	920
Suzuki, Y.	1648	Tanaka, H.	96, 1636, 2617	Thompson, W.I., III.	1355
Svačina, J.	422	Tanaka, K.	412, 414	Thomson, R.G.	45, 1873
Svalbonas, V.	2639	Tang, H.T.	1359	Thomson, R.K.	2275
Svoboda, J.	2211	Tang, S.C.	1127	Thornhill, R.J.	818
Swan, H.W.	478	Tang, Z.-q.	2023	Thurgood, D.A.	2532
Swan, M.A.	912	Tangri, K.	2469	Tietjen, B.W.	1735
Swannell, P.	1772	Tani, J.	352, 2396, 2398, 2603, 2607	Tilly, G.P.	1820
Swanson, S.R.	2226	Tanna, H.K.	1615, 2234	Ting, T.C.T.	1707
Sweet, L.M.	183, 747, 1437	Tanner, A.E.	1223, 2558	Tipton, A.G.	1445
Swigert, C.J.	1337	Tao, K.	126	Tirinda, P.	306, 1235
Swinerd, G.G.	105	Tauffkirchen, W.	1992	Tischler, V.A.	2090
Syamal, P.K.	2189	Tay, C.H.	1913	Tjøtta, J.N.	2430
Syed, A.A.	1088	Taylor, A.D.	1148	Tjøtta, S.	2430
Sylvan, O.	681	Taylor, C.M.	506	To, C.W.S.	1087, 1123
Symonds, P.S.	1315, 1324	Taylor, J.I.	582, 675, 2656	Toda, A.	2323
Szemplinska-Stupnicka, W.	1331	Taylor, M.E.	2418	Todd, M.A.	543
Szenasi, F.R.	521	Taylor, R.B.	284	Tokaji, K.	1717
Szopa, J.	957, 2259	Taylor, R.E.	265, 2317	Toki, K.	1826
		Taylor, S.M.	51, 817, 934, 2622	Tomassoni, J.E.	906
		Teh, C.E.	995, 2150	Tomizuka, M.	1548
		Temarel, P.	927	Tomlinson, G.R.	1078, 1105
		Templin, K.W.	1354	Tondl, A.	410, 1172
		Terada, K.	2564	Tong, P.	746, 1203
		Terasawa, T.	2129	Tong, Y.L.	724
		Terauchi, Y.	1649	Tonndorf, J.	1816
		Terborg, G.E.	1340	Torres, M.R.	23
		Teschner, W.	2261	Torset, O.P.	1912
		Tester, B.J.	2234	Torvik, P.J.	660, 1336
		Thailer, H.	1706	Towers, D.	919
		Thasanatorn, C.	2336	Touratier, M.	1767
		Thatcher, C.	1093, 1094, 1095	Traill-Nash, R.W.	1756
		Theis, K.	1736	Tran, A.D.	2600
				Tran, H.T.	2446

T

Tabaddor, F.	2166
Tabarrok, B.	2491
Taber, L.A.	2091
Tada, N.	2375
Tada, Y.	1145
Tagart, S.W., Jr.	1706
Tait, R.J.	2610
Takada, S.	1594
Takagi, M.	2533
Takagi, S.	2434

Tran, P.T. 1287
 Trankle, T.L. 849
 Trautmann, C.H. 2419
 Trautmann, G.H. 797
 Traveaux, P.J. 2649
 Travi, S. 1823
 Trayner, B.T. 2576
 Tree, D.R. 1089, 2227
 Trent, B.C. 2540
 Trifunac, M.D. 2195
 Trivett, D.H. 1700
 Trn, R.M. 415
 Troeder, C. 1240, 1650, 2525
 Troeder, Ch. 1815
 Trommer, W. 1996
 Trubert, M.R. 48
 Trunzo, R. 2051
 Truong, K.T. 1287
 Tsai, M.S. 380
 Tseng, K. 714
 Tsirk, A. 1198
 Tsubokura, K. 327, 2367
 Tsuda, Y. 955
 Tsui, C.C. 158
 Tsui, M. 2130, 2131
 Tsui, Y.T. 158
 Tsukikawa, T. 1832
 Tsurui, A. 2643
 Tsushima, N. 1645
 Tuccio, M. 1151
 Turcic, D.A. 1489, 2378
 Turczyn, M.T. 571
 Turhan, D. 167
 Turkel, E. 1966
 Turnbow, J.W. 1223
 Turner, C.D. 2345
 Turner, J.D. 295
 Turula, P. 1678
 Tustin, W. 1357
 Tuten, J.M. 274
 Tuttle, M. 2519
 Tylikowski, A. 868
 Tzeng, S.-T.K. 1299
 Tzuang, S. 827

U

Überall, H. 148
 Udwardia, F.E. 2678

Ueberall, H. 2045
 Ueda, T. 2146
 Ueda, Y. 1710
 Uematsu, R. 588
 Uematsu, S. 2371
 Ueyama, H. 1832
 Uffer, R. 1706
 Uicker, J.J., Jr. 1554, 1555
 Ujishashi, S. 359, 1680
 Ukeje, E. 1978
 Ulbrich, H. 2572
 Umetsato, K. 1917
 Underwood, P. 1982
 Underwood, P.G. 712
 Unruh, J.F. 2555
 Unz, H. 1034, 1294
 Urbanczyk, M. 1977
 Urbanik, T.J. 2076
 Ushijima, Y. 2323
 Usui, T. 1496
 Utku, S. 2124

V

Vaicaitis, R. 98
 Valentin, R.A. 801, 803
 Valid, R. 1056, 2019
 van Baten, T.J. 978
 Van Benschoten, J. 1104
 Van Buren, A.L. 1534, 1700
 Vance, J.M. 503, 725, 1579, 2592
 Van Dao, N. 647, 1763
 VandenBrulle, P.J. 304
 Vanderhart, D.L. 2012
 van der Kooij, J. 2333
 Vanderpool, M.E. 1681
 Vandiver, J.K. 85, 1428
 Van Gemert, D.A. 2536
 Van Haren, J. 322
 Van Honacker, P. 322, 1607
 van Nunen, J.W.G. 881
 van Willigenburg, J.J. 1206
 Varadan, T.K. 1492
 Varadan, V.K. 1699
 Varadan, V.V. 1699
 Varga, T. 1992

Varpasuo, P. 60
 Vashi, K.M. 684, 822
 Vaske, P. 428
 Vassilopoulos, L. 1642
 Vasudevan, R. 889
 Vatterott, K.H. 1241
 Vaughan, D.K. 1359
 Vaughan, V.L., Jr. 751, 930
 Vdovjak, J.W. 1859
 Velinsky, S.A. 902
 Veluswami, M.A. 120, 121
 Veneziana, D. 2561
 Venkatesan, C. 1461
 Venkayya, V.B. 929, 1454
 Vepa, R. 2
 Verchery, G. 2028
 Verheest, F. 2450
 Verma, J.P. 2384
 Vermeulen, P.J. 634
 Vernière De Irassar, P.L. 1905
 Vestroni, F. 820, 963
 Větrovec, K. 21
 Viano, D.C. 2091, 2327
 Victor, F. 2518
 Viegas Gago, A.F. 982
 Vijay, D.K. 367
 Villaverde, R. 16
 Vincent, J.H. 2559
 Vincent, R.Q. 2412
 Virchis, V.J. 1588
 Visscher, W.M. 1304
 Viswanathan, S.P. 553
 Viti, G. 1823
 Vlach, J. 1771
 Voelsen, P. 1847
 Vogel, W. 1676
 Vogt, G. 2373
 Vogt, L. 570
 Volcy, G.C. 37, 928
 Volkert, O. 1637
 Vömel, M. 1997
 von Buseck, C.R. 910
 von Reyn, T. 2230
 Von Riesemann, W.A. 28
 Voorhees, C. 2089
 Voorhees, C.R. 150
 Voros, G. 2454
 Vosikovsky, O. 2642
 Voyiadjis, G.Z. 1927
 Vulfson, J.I. 1655
 Vullo, V. 6, 7

W

Waas, Ph.D.G.	1830	Wasner, O.	232	White, K.R.	1099
Waberski, A.	615, 2489	Wasserman, D.E.	861	White, M.R.	560
Wachel, J.C.	521, 1686	Watanabe, J.	1832	White, R.	1667
Wachter, J.	606, 2593	Watanabe, K.	2312, 2397, 2471	White, R.A.	902
Wada, H.	2298	Watanabe, N.	2122	White, R.G.	995, 2096, 2150
Wagner, P.	1281, 1950	Watanabe, T.	1495	White, R.N.	27
Wagner, R.	689	Watanabe, Y.	2552	Whitehead, D.S.	1478
Wahi, K.K.	2540	Waters, D.M.	1877	Whitehead, D.W.	1477
Waine, B.R.	1201	Waters, P.E.	1165	Whitesell, J.E.	1778
Waldon, C.A.	1993	Watkins, J.C.	717	Whitford, L.	2100
Walford, T.L.H.	1239, 2571	Watson, H.E.	265	Whitney, A.K.	1953, 1954
Walgrave, S.C.	548	Watson, L.T.	2173	Whitney, M.G.	646
Walker, A.W.	1311, 2004	Watt, B.J.	1838	Whitt, J.B.	2244
Walker, K.C.	900, 901	Watt, W.	205	Whittaker, A.R.	880
Walker, R.	1880	Watters, R.B.	956	Whitton, P.N.	1335
Walker, R.E.	639	Wauer, J.	1829	Wicher, J.	1235
Walker, S.	894	Waugh, C.B.	28	Wierzbicki, T.	357, 1762
Wall, D.J.N.	1699	Wearing, J.L.	2588	Wieser, P.	326
Wallace, M.M.	625	Weaver, D.S.	2169, 2170	Wilby, E.G.	936, 1213
Wallace, R.I.	233	Weaver, H.J.	888	Wilby, J.F.	936, 1213
Wallace, T.F.	47	Weaver, R.L.	2181	Wildheim, J.	2203
Waller, H.	429, 430	Weber, K.	1573	Wilding, R.	2089
Walpert, H.	2198	Weck, M.	2376	Wilkinson, C.D.W.	1514
Walsh, M.J.	1632	Wedig, W.	464, 971, 2018, 2679	Wilkinson, D.H.	82
Walter, C.E.	233	Weglein, A.B.	1300, 1301	Wilkinson, R.H.	2389
Walter, J.L.	781	Wegner, J.G.	1882	Willey, E.	787
Walton, W.	1835	Wehage, R.	2680	Williams, R.	1986
Walton, W.S.	636	Weimer, F.C.	2273	Williams, R.J.	2492
Wambsganss, M.W.	1019	Weiming, T.	240, 386	Williams, R.S.	449
Wan, F.Y.M.	310	Weiner, E.O.	259	Willis, J.R.	1045, 1046, 1302
Wandrisco, J.M.	64	Weingarten, V.I.	2619	Wilshire, W.L., Jr.	1610
Wang, A.J.	2361	Weinstock, H.	920, 2553	Wilson, D.	1744
Wang, B.P.	2269	Weiss, R.A.	1107	Wilson, E.L.	1426, 1590
Wang, C.C.	2300, 2494	Weissmann, G.F.	2440	Wilson, J.C.	731
Wang, K.L.	2113, 2114	Wells, W.R.	1221	Wilson, J.F.	2385
Wang, P.C.	30	Wenger, W.A.B.	2178	Wilson, R.B.	2374
Wang, S.J.	1592	Wenlong, L.	2462	Wiltzsch, M.	331
Wang, T.-M.	1662	Wernicke, G.	1730	Winkler, C.	2684, 2685
Wang, X.	1238	Wesley, D.A.	893	Winkler, C.B.	61, 182
Wang, Y.F.	364	West, B.	1618	Winter, R.	46, 2190
Wang, Y.-g.	2424	West, H.H.	83	Winterstätter, A.	2458
Wanhill, R.J.H.	953	Westermo, B.D.	2123	Witmer, E.A.	663, 2125
Warburton, G.B.	1881	Westervelt, P.J.	2185	Witte, G.	1532
Ware, P.M.	2579	Westine, P.S.	643	Wittlin, G.	1572
Warren, R.E.	1414	Wevers, L.J.	1576	Wittman, L.J.	497
Warring, R.H.	943	Wey, J.	5	Witwer, K.Z.	1746
Washizu, K.	1253	Whaley, P.W.	112	Włodarczyk, E.	2186, 2191
		Wharf, J.H.	568	Wojewódzki, W.	2408
		Whiston, G.S.	89	Wojno, W.	357
		White, B.A.	197	Wolf, C.	232
		White, E.R.	1370	Wolf, J.A., Jr.	2470

Wolf, J.P. 242, 251, 400
 Wölfel, J. 162
 Wolff, F.H. 484, 608, 2118, 2268
 Woltornist, W. 2080
 Wood, W.L. 1560
 Woodhouse, J. 2499
 Woodsum, H.C. 2185
 Woodward, K.A. 2133
 Woodward, R.P. 1413
 Woollett, R.S. 671
 Woomer, E. 1543
 Wormley, D.N. 1427, 1434, 1811
 Worthington, P.J. 1342
 Wright, J.P. 1594
 Wright, R.N. 2691
 Wroblewski, J.E. 1787, 1788,
 1793, 1794
 Wu, J.H.T. 1519, 1981
 Wu, J.J. 2127, 2128
 Wu, J.-T. 1897
 Wu, S.M. 2059, 2306, 2476
 Wu, S.T. 239
 Wu, W. 1312
 Wu, Y.-s. 1870
 Wulff, W. 1146
 Wyskida, R.M. 574, 1474
 Wyssmann, H.R. 516

X

Xianquan, D. 2462
 Xistris, G.D. 191

Y

Yaghmai, I. 2115
 Yam, K. 1234
 Yamada, G. 92, 337, 358, 768,
 1261, 1262, 1917, 2143
 Yamada, M. 1407
 Yamada, T. 1717
 Yamagishi, K. 2344
 Yamaguchi, T. 1268
 Yamaki, N. 965, 966, 2398

Yamamoto, S. 29, 1832
 Yamamoto, T. 1403, 1407
 Yamane, T. 2344
 Yamazaki, Y. 1705
 Yan, L.-T. 2049
 Yanabe, S. 1575, 2522
 Yang, C.S. 2250
 Yang, C.Y. 1423, 1424, 2066
 Yang, D. 441
 Yang, G.P. 1238
 Yang, H.H. 1238
 Yang, J.C.S. 2198
 Yang, J.N. 1822
 Yao, J.T.P. 2062
 Yang, T.Y. 890
 Yang, W.H. 1086
 Yaniv, S.L. 150
 Yano, S. 219
 Yanome, M. 2364
 Yao, J.T.P. 1777
 Yates, D.G. 688
 Yates, J.E. 1509
 Yau, W.F. 1518
 Yazaki, K. 2318
 Yeager, D.M. 387
 Yeager, W.T., Jr. 1585
 Yee, G. 1359
 Yeh, H.H. 2034
 Yen, B.T. 1186, 1187
 Yen, C.-L. 1017, 2410, 2611
 Yen, D.H.Y. 774
 Yerges, J.F. 631
 Yeung, K.S. 1127
 Yim, C. 773
 Yin, S.K. 35
 Ying, S.P. 394, 526
 Yoda, K. 2393
 Yokoi, M. 1307
 Yokoya, Y. 2434
 Yokoyama, Y. 2061
 Yoneda, R. 2417
 Yonkovich, G. 301
 Yoneya, T. 1840
 Yoo, C.H. 1910
 Yoshida, H. 1955
 Yoshida, K. 1840
 Yoshimura, T. 2471
 Younes, Y.K. 1480

Young, B. 1147
 Young, C. 2540
 Young, J.A. 891, 2331
 Young, J.Y. 1908
 Young, M.I. 1412
 Youngdahl, C.K. 801, 803
 Yu, B.-K. 1254, 1953
 Yu, I.-W. 418
 Yu, Y.H. 1225, 1586
 Yuceoglu, U. 824
 Yun, C.B. 30
 Yuruzume, I. 325, 2369
 Yuzawa, M. 1973

Z

Zaghlool, S.A. 1101
 Zak, A.R. 1269
 Zak, K. 121
 Zandt, G. 254
 Zedan, M.F. 1908
 Zeid, I. 8
 Zeng, C.-h. 1870
 Zettlemoyer, N. 238, 1189
 Zhongquan, X. 248
 Zhongmin, Y. 2462
 Zhou, Z.-w. 2424
 Zhuravlev, V.F. 2568
 Ziaran, S. 1242
 Zielke, W. 1598
 Zimmerman, H. 1133
 Zimmerman, R.M. 1099
 Zimmermann, T. 2168
 Zinn, B. 1611
 Zinn, B.T. 1505
 Zirin, L. 1580
 Zlokolica, M.Z. 1557
 Zogg, H. 228
 Zorumski, W.E. 1864
 Zorzi, E. 2662
 Zorzi, E.S. 831
 Zubavičius, L. 595
 Zwicke, P.E. 284
 Zvolanek, I. 2516

ANNUAL SUBJECT INDEX

A											

Acoustic Resonators	1174					Aerodynamic Characteristics					476	417	1709
						1351	1102	1453					
						1221	1442						
Acoustic Response						Aerodynamic Damping							
391 842 1293	2465			1918								759	
1031 2142 1513												2009	
Acoustic Scattering						Aerodynamic Excitation							
140 151 1702	2185			139							287	1429	
				349		Aerodynamic Loads							
				2429		1220	1791	1752	714	66	937	1388	1159
Acoustic Signatures						1620		1792	1624	1226	1057	1389	
1970 1541						1790					2117	2009	
Acoustic Spectra						Aerodynamic Noise							
1690									754		1487		
Acoustic Tests						Aerodynamic Response							
1811 1832	995					use Aerodynamic Stability							
2011						Aerodynamic Stability							
Acoustic Waves											1567		
2390 1562				387 1508		Aeroelasticity							
									872 1463 1764				
Acoustical Data						1652							
Use Experimental Data													
Active Control						Agricultural Machinery							
2211	284 1975			1627 498					744 745		537 578		
				1258									
Active Damping						Air Bags (Safety Restraint Systems)							
420 2211	2565			657	1989						2327		
830					2209	Air Blast							
											1317		
Active Flutter Control						Airborne Equipment Response							
1460 1452				1457 1458 1459		681 112				556 287			
1622				2357 1868 1619		682							
Active Noise Control						Air Compressors							
	2174					use Compressors							
Active Vibration Control						Air Conditioning Equipment							
2210										1196			
Actuators										1976			
					1299	Aircraft							
						210 41	42 43	44 285	936	47	118	289	
Aerial Explosions						290 1221	752 1213	714 1015	1016	937	228	1159	
1521											(cont'd)		
Abstract													
Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2604	2605-2891	
Volume 13													
Issue:	1	2	3	4	5	6	7	8	9	10	11	12	

Aircraft (continued)

1220 1371 1332 1623 1224 1445 1866 947 668 1219
 1440 1461 1442 1793 1794 1455 2086 1137 1218 1459
 1460 1621 1452 2343 2345 2556 1457 1348 1619
 1870 1751 1462 1537 1458 1869
 1871 1622 1617 1568
 1991 2082 1867 1618
 2237 2558
 2357

Aircraft Carriers

704

Aircraft Engines

1370 1033 1745 1547 1369
 1293 1727 2029
 2117 2049
 2557

Aircraft Equipment

1147

Aircraft Equipment Response

2236

Aircraft Noise

40 51 282 283 934 935 1216 817 1148 49
 680 381 932 753 1214 1155 1446 1447 1858 1629
 1390 1211 1032 933 1444 1215 1616 1857 2338 1859
 1610 1631 1212 1443 1614 1615 2047 2339
 1630 1861 1392 1613 1864 1865 2337
 1860 2341 1612 1863 2084 2085
 1862 2083 2234 2555
 2342
 2622

Aircraft Seat Belts

1222

Aircraft Seats

1222

Aircraft Vibration

1213

569

Aircraft Wings

680 1752 1453 1454 1085 286 1217 1868 929
 1620 2035 1456 1567

Airfoils

1441 2103 1624 1968 1509
 1709

Airframes

936 1217

Airport Noise

use Airports

Airports

441 632 2083 1464 2087
 2622 2544

Algorithms

202 1133 424

Aligning

use Alignment

Alignment

510 511 512 513 334 596 588
 1643 514 708
 2573 1694

Aluminum

2343 2354 835
 995
 1525

Ammunition

812 1883 645

Amplifiers

1075

Amplification

1865 1966

Amplitude Analysis

2230 2524 1836 1658

Amplitude Data

2278

Amplitude Measurement

174

Amplitude Modulation

1334

Analog Simulation

450 532

Anechoic Chambers

2014

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2891

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Axisymmetric Bodies

1711

638

Axisymmetric Vibrations

2400

1945

Axle Acceleration

902

Beams (continued)

970 1041 1662 1663 2154 1875 967 1888 1249
1040 1661 1762 1783 2204 1905 1247 2128 1659
1140 1691 1902 1903 2214 2125 1337 2598 1829
1250 1901 2122 2123 2384 2385 1907 1899
1660 2511 2382 2383 2127 2129
1900 2387 2589
2270 2599
2600

Beams - Columns

2115

Bearings

70 71 72 73 74 75 76 77 78 69
80 581 582 583 204 185 176 317 318 79
300 591 1482 1643 584 315 316 507 588 209
320 1181 1582 1813 1644 585 486 587 1108 319
500 1481 1642 1893 1694 955 506 1237 1238 499
580 1641 1892 2573 2104 1645 586 1577 1638 589
590 1891 2572 2583 2574 2105 956 2107 2048 699
760 2571 2582 2584 2365 1646 2577 2108 1239
1480 2581 2634 2575 1886 2568 2109
1540 2585 2036 2578 2569
1890 2106 2688 2579
2110 2366 2659
2240 2506
2570 2576
2580
2660
2670

Beat Frequency

2576

Bellows

1483

Belt Drives

2305 1817

Belts (Moving)

321 234

Bernoulli-Euler Method

2385 2127 1249
2599

Bernoulli Theory

1906

Bevel Gears

1648 1649

- B -

Baffles

2151 2563 944

Balancing

use Balancing Techniques

Balancing Techniques

700 701 702 703 2474 445 596 697 2668 2669
1741 1742 1543 2664 1115 1116 1367 2688
2661 2252 1743 1365 1336 2667
2532 2253 2665 2666
2662 2663

Ball Bearings

185 2568 319
955 1239
1645 2659
2105

Barges

1841

Bars

2644 2445 1246 337 338 339
638

Base Excitation

2292 2123 2095 2387 2098 2097
2199
2409

Beams

90 91 92 93 184 625 966 87 88 89
340 341 342 313 964 965 1906 267 968 469
450 451 572 343 1324 1475 2126 667 1248 539
610 611 1082 473 1904 1495 2386 767 1338 609
710 971 1492 1493 1954 1765 867 1588 969

(cont'd)

Abstract

Numbers: 1-217 218-483 484-719 720-888 889-1187 1188-1402 1403-1574 1575-1799 1800-2048 2049-2289 2290-2504 2505-2601

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Bibliographies
 1400 481 482 483 1794 1795 1166 1167 1788 1789
 1790 1401 1402 1793 1796 1787 1798
 1791 1792 1797

Bifurcation Theory
 1761

Bird Strikes

1618

Bispectral Analysis
 1112

Blade Loss Dynamics
 222
 2292

Blades
 310 311 212 313 224 865 66 67 948 579
 950 951 312 873 314 2566 1477 1478 1229
 1640 1931 952 953 524 1727 1888 1889
 1720 2041 2102 2103 954 2037 2038 2039
 2040 2101 2362 2363 1744 2239
 2100 2361 2364
 2360 2511

Blast Effects
 643

Blast Excitation
 640 641 642 853
 2311

Blast Loads

2008

Blast Resistant Construction
 use Blast Resistant Structures

Blast Resistant Design
 use Blast Resistant Structures

Blast Response

619
 2629

Blowdown Response
 2172

Blowers
 1174
 1784

Boilers
 1353 134 2136 129

Boiling Water Reactors
 81 23

Bolotin Method
 978

Bolts
 1991 1653 958

Bonded Structures
 2343 2589

Bond Graphs
 use Bond Graph Technique

Bond Graph Technique
 1380 841 462 1755 177
 1587

Bones
 2091

Booster Rockets
 561 562

Boundary Condition Effects
 1940 1011 124 1925 1326 867 2608
 1924

Boundary Element Technique
 1982

Boundary Layer Damping
 1323

Boundary Layer Excitation
 2606

Boundary Value Problems
 1762 113 1254 2025 397 709
 2023 2489

Box Beams
 236

Box Girders
 1185 1186 1187 1189

Box Type Structures
 246

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2299 2290-2504 2505-2891

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Braces											Calibrating					
240	1194					2178					1702	2234	1726			
Braking Effects											Calibration					
1462	2684 2685 1476										use Calibrating					
	2686															
Branched Systems											Cam Followers					
391	1024					2676					2378 1489					
	2054															
Bridges											Cams	1489				
1190 11 12 253	1185 236 237 238 729										1489					
1820 881	2075 256 1167 728 1099															
2310 1191	1166 1187 1188 1189															
	1186 1588 2309															
						1938										
						2438										
Buildings											Cantilever Beams					
240 241 242 13 14 15 16 17 18 239											90 2391	363 184	967 1888 769			
830 731 882 243 244 245 246 267 658 1399											1210	1663 2124	1907 1908			
1420 1591 1192 533 1194 1255 1166 1167 1398 1589											1680		2387			
1590 1821 1822 613 2064 1195 1196 2537 2189																
	1921 2062 633 2194 2535 2536															
	2311 883															
	2561 1004															
	2691 1193															
	1823															
	2063															
Bumpers											Cantilever Plates					
						1637					1000 112	114 855				
Buses											2294					
						1207										
- C -																
Cable-Stiffened Structures											Caps (Supports)	123				
881						1909					Cargo Transportation					
971											1274					
1191											Cascades					
1421											2101					
Cables (Ropes)															1477 1889	1889
2380 1491 962 83 84 85 766 607 608 2119											2567					
	963 1364 765 1657 1898										Catenaries					
	1245 2388										597					
Abstract																
Numbers: 1-217 218-483 484-718 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691																
Volume 13																
Issue: 1 2 3 4 5 6 7 8 9 10 11 12																

Cell-to-Cell Mapping
2262 2263

Centrifugal Pumps
2533

Cepstrum Analysis
1364

Ceramics

Chain Drives

Chatter
880 231 232 2574
531 1182

Chimneys
971 972

Circular Cylinders
1911 1494

Circular Membranes
1930

Circular Plates
100 101 102 1003 1934 1935 2147 358 779
1930 1671 1932 1933 2144 2145 2157 1268 1259
2400 2332 2395

Circular Saws
2362 1258 1479

Circular Shells
360 1681 2612 124
2164

Clay Soils
2466

Clearance Effects
1240 1802 1495
1650 1895

Coherence Function Technique
394

Collocation Method
2028

Collapses
use Failure Analysis

Collision Research (Aircraft)
use Crash Research (Aircraft)

Collision Research (Automotive)
900 551 1632 693 904 155 906 277 1468 689
2190 901 2502 1313 1314 905 1606 1127 2078 899
2330 1373 2354 1605 2326 2327 2328 2329
2503 2554 2355 2488

Collision Research (Railroad)
715 548 549

Collision Research (Ships)
1373 2336

Columns
251 772 773 975 2536 97 1059
1665 347

Columns (Supports)
2391 2133

Combination Resonance
1059

Combustion Engines
2587

Combustion Noise
2323 2085

Compacting
2544

Complete Quadratic Combination Method
1590

Complex Structures
2483

Component Mode Analysis
1381

Component Mode Synthesis
2590 2292 1608 2239

Composite Materials
210 1041 152 414 625 426 837 1628
660 1741 412 1454 776
680 2181 612 1046
1440 1302
1342

Abstract

Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2681

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Composite Structures
 1000 481 2166 1937 998 1039
 1041 1038 1929
 1991 2149
 2031 2439

Composites
 944

Compressor Blades
 2100 1744 855 67 948 579

Compressors
 521 522 523 604 495 496 497 518 1739
 2301 2532 2593 1174 515 516 727 2009
 725 536
 2665

Computer-Aided Techniques
 80 691 172 163 1714 205 676 877 1208 509
 1370 931 812 473 1794 706 1558 959
 2000 1742 1713 2664 1546 2248 1369
 2010 2322 1793 2356 2668 1579
 2680 2492 1843 2596 1749
 2652 1873 2299
 2073 2319
 2253
 2663

Computer Programs
 420 291 22 293 74 5 46 7 18 269
 470 311 232 633 204 205 206 207 218 469
 540 471 292 653 474 405 466 367 268 1069
 890 801 402 713 364 475 476 417 418 1149
 1150 1151 472 773 714 715 736 467 428 1359
 1390 1201 712 813 854 855 856 477 468 1389
 1980 1391 722 853 874 1155 1006 607 478 1559
 2120 1521 862 1153 1154 1255 1056 717 858 1779
 2510 1611 892 1193 1224 1455 1146 857 918 1789
 1711 1152 1393 1454 1465 1466 897 1108 1889
 1891 1392 1453 2044 1565 1566 1127 1148 2039
 2041 1522 2043 2064 2035 1786 1147 1228 2069
 2321 2042 1913 2094 2045 2036 1387 1388 2159
 2282 2283 2124 2125 2166 1477 1578
 2342 2503 2284 2275 2286 1567 1618
 2502 2683 2504 2285 2686 1657 1678
 2682 2684 2685 1687 2038
 2037 2088
 2167
 2177
 2687

Computerized Simulation
 1632 864

Concentric Structures
 1677

Concrete Construction
 1195 479

Concretes
 2541 1962 1363 1424 15 106 658 2589
 2601 2392 1963 1838
 2621 2543

Condensation Method
 1381 2266

Configuration Effects
 use Geometric Effects

Conformal Mapping
 1562 2025

Conical Shells
 1281 2607 2159

Connecting Rods
 648

Consistent Mass Method
 1913

Constitutive Equations
 251

Constrained Structures
 1713 1714
 1903

Construction Equipment
 2545 2546 57 538 249

Construction Industry
 2182

Contact Stresses
 1126

Contact Vibration
 601

Containers
 635 1946 917 749
 2076 1947 1949
 2347

Abstract

Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Crash Research (Aircraft)
 930 751 402 1223 474 45 46 2168
 2190 1222 1373 2558
 1572 1873
 1872

Crashworthiness
 2190 1222 1223 715 2326 47 548 549
 2558

Critical Damping
 1901 1082 423 2208

Critical Excitation Method
 1198

Critical Response Spectra
 154

Critical Speeds
 870 722 2053 475 1408 509
 1170 2512 1575 2508
 2050 2522

Cross Correlation Technique
 463 1446
 2003

Cross Spectral Method
 2233

Curved Beams
 1910 1662 1783 2386 87 768 609
 337

Curved Ducts
 1961

Curved Plates
 1041 1257

Cushioning
 use Impact Shock Insulation

Cushioning Materials
 use Packaging Materials

Cutting
 1182

Cyclic Loading
 440 592 2133 2176 2178 599
 2222

Cylinders
 770 771 612 973 974 95 96 878 2179
 1010 1911 1252 1253 1254 855 346 2388 2389
 1050 2131 2132 2123 1494 1715 1836 2629
 1100 2161 2413 1664 2415

Cylindrical Beams
 1337 1338

Cylindrical Bodies
 use Cylinders

Cylindrical Shells
 120 121 782 403 124 1015 426 1017 118 119
 360 771 1012 783 1014 1275 1016 1677 368 359
 1010 781 1282 973 1944 1405 1276 2407 1498 1679
 1280 1011 1682 1013 2164 1715 1676 1678 2409
 1680 1681 1762 1673 2105 2406 2608 2609
 1940 1941 1942 1943 2165
 2180 2161 2162 2163
 2390 2611 2612
 2410
 2610

- D -

Damage Prediction
 243 254 735
 2225

Damped Modes
 1756

Damped Structures
 1070 2391 2022 1923 2144 1376 407 1078
 2023

Damped Systems
 1760 2143 2208
 2218

Damper Locations
 875

Dampers
 1080 421 2213 214 875 2116 419
 2633 2214 2565 1989
 2634

Abstract

Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Damping										Design Techniques (continued)									
580	1041	2212	213	1584	1805	1076		2058	1079	530	1411	1142	1473	854	1145	2356	877	1778	789
1200	1081	2532				2126			1309	750	2281	1892	1893	1104	1565	2646	2427	1958	959
									1319	1510		1992	2013	1244	2425			2358	1199
Damping Characteristics										2680		2093	1564					2558	1579
1340				384	2585			2218					1674						1789
													2394						
Damping Coefficients										Detectors									
590	1651	422	223		725	316		308	1129	1530		1872						2078	
1660	1911	542	603		1725	586		518	1339										
2110	2291	1582	653	654	1885	656		558	1809	Diagnostic Instrumentation									
2230	2571	1642	1193		2105	2376		1758		1110									
2550		2582	1653		2215	2466		1828		Diagnostic Techniques									
		2632	2583							1110	1111	442	443	444	185	696	677	698	699
Damping Effects										1360	1361	1112	1113	1114	705	716	697	718	1109
1560		502	1903	294	605	826	377	348	219	2470	1501	1362	1363	1364	2475	2016	2017	1108	1369
2050		2522		424	825	1556	2677		499			1541	1542		1574	2655	2656	2657	1738
2170		2612		584					2049			2251							2468
2440				724								2471							2658
Damping Materials										Diaphragm Couplings									
		2362		1704													596	1187	
Damping Values										Diesel Engines									
use Damping Coefficients										720		1542		324	2325		527	878	229
Dams												2252							
	1831	1422	253	1424	1595	1166	1167		479			2552							
	2541	2202	1363			1596	1597			Difference Equations									
		2542	1423			2066	2067												1379
			2543				2317			Differential Equations									
Data Presentation												2482		2264				1378	
150		2362						178		Digital Filters									
Data Processing										2460	1731	2002	1123		1535			429	
		1372		704		576		188	2319	Digital Simulation									
		1892						2488											
		2062											33						
Data Reduction										Digital Techniques									
use Data Processing												1532	2073	1734		1106		168	
Decay Laws												2372							
								1309		Dimensional Analysis									
Describing Function Approach																1565			
						2486				Dimensional Measurement									
Design Techniques																			1799
80	591	62	3	164	315	6	7	448	209	Direct Computational Method									
210	1181	72	473	314	1075	2216	787	628	749										
										(cont'd)									

Abstract											
Numbers: 1-217 218-483 484-719 720-888 887-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2891											
Volume 13											
Issue:	1	2	3	4	5	6	7	8	9	10	11
											12

Direct Fourier Synthesis

2026

Discontinuity-Containing Media

2620 1321 2162 1014 1045 1046 1667 78 389
2445 1968 2609

Discs

use Disks

Disk Springs

56

Disks

use Disks (Shapes)

Disks (Shapes)

2040 1091 1002 2143 224 1936 1258
2112 2363 994 1178
2362 2148
2512

Displacement Analysis

1953

2019

Displacement Measurement

1092 434 105 668
435

Displacement Transducers

433 1996

Domes

1005 1006 1008

Doppler Effects

189

Double Summation Procedure

1283

Doubly Asymptotic Approximation Method

1982 2254

Drilling Platforms

2550 1837 1838 1839
2317

Drills

2381 2476 627 1419
1819

Drillships

use Drills and Ships

Drive Line Vibrations

527

Drive Shafts

1802 2525

Drop Tests

574

Ducts

170 381 382 383 624 135 136 1037 1288 1959
380 1291 1032 573 1034 565 1036 1957 1958
610 1471 1292 1033 1234 1035 1506
1290 1961 2422 1293 1294 1295 1956
1690 2421 1853 2174 1505
1960 2173 1955
2420 2423 2175
2620 2563

Duffing's Differential Equation

1770

Dynamic Absorbers

2093

Dynamic Balancing

703

Dynamic Buckling

120 121 122 123 664 1665 366 97 88
361 1692 784 796 347 2408
2121

Dynamic Data System Technique

851 2306 2059
2476

Dynamic Excitation

use Dynamic Response

Dynamic Loads

use Dynamic Response

Dynamic Modulus of Elasticity

1071

Dynamic Plasticity

1040 1934 88

Dynamic Programming

1773 1774

Dynamic Properties

746

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Dynamic Relaxation
1201

Dynamic Response

1440 821 2272 743 2114 195 346 367 318 79
1151 2113 1897 1208 229
2099

Dynamic Shear Modulus

2466

Dynamic Stability

1761 1412 1394 585 656 498

Dynamic Stiffness

70 1041 732
1901

Dynamic Stress Concentration

2024 1699

Dynamic Structural Analysis

1060 81 712 843 1224 825 166 1057 18 199
431 1754 1135 336 198 709
2401 2264 766 1558

Dynamic Structural Response

use Dynamic Response

Dynamic Synthesis

1654

Dynamic Systems

1561 2262 2263 466 1768
2261

Dynamic Tests

180 31 2542 233 24 25 1536 1197 598 309
540 181 543 694 685 1667 888 559
930 541 603 1314 1605 1539
1580 1251 1313 1854
2653

Dynamic Vibration Absorption (Equipment)

1140 54 1236 298 419
1989

Dynamic Weighing Method

741 1096

- E -

Ears

1267

Earthquake Damage

371 1192 243 254 795 2066 2627 1198
1591 1423 1424
2541

Earthquake Prediction

1318

Earthquake Resistant Design

use Earthquake Resistant Structures

Earthquake Resistant Structures

2601 1673 2195 1777 738
2691

Earthquake Response

180 731 242 153 244 1255 1596 1277 1838
260 1921 1712 1503 1594 1705 2176 2537
820 2561 1962 1673 2044
860 2392 1963
2540 2543

Earthquake Simulation

2542 1194 637
2674

Earthquakes

891 1072 823 2194 1826 797 1319
1831 2309

Eigenvalue Problems

710 221 842 193 924 2025 196 457 1118 1119
870 1941 1522 2683 1754 2495 456 2477 2478
2022

Eigenvalues

use Eigenvalue Problems

Elastic Core-Containing Media

1265

Elastic Foundations

790 775 2157 778 1249
1259

Abstract

Numbers: 1-217 218-483 484-719 720-868 867-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2681

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Elastic Half-Space
2400 252 1936
2312

Elastic Media
2490 2191 1302 413 405 1086 1059
1552 1983 1526 1319

Elastic-Plastic Properties
361 664 126
1344 1066
1346

Elastic Properties
252 1345 86 837
426 997
2606 1347
1527
2397

Elastic Waves
1300 171 713 974 145 136 847 388 389
991 733 1034 1035 1046 1697 848 1699
1301 1043 1044 1045 1696 1827 1698
1961 1303 1294 1305 2446 1967 2028
2181 2443 1304 1695 2447 2448
2421 1374 2687
1514
2444

Elastically Restrained Edges
100

Elasticity

1789

Elasticity Theory
996 1107

Elastodynamic Response
2202 1527

Elastohydrodynamic Properties
2594

Elastomeric Bearings
2574 1646
1886

Elastomeric Dampers
831 656

Elastomeric Seals
2594

Elastomers
2570 631 1885 1886 2097 58
1651 2526 1528

Elastoplastic Properties
2260 2172 45 1349

Electric Drives
532

Electric Generators
use Electric Power Plants

Electric Power Plants
791 394 25 26 887 28
1811 1415 386 1427 208
1146 738
1416 1488
2548

Electric Systems
2530

Electric Vehicles
233 899

Electromagnetic Properties
1814

Electronic Instrumentation
1734 626 1357
696

Elevated Railroads
919
1439

Enclosures
1030 1031 2602 943 14 816 98 1029
1013 1028

Energy Absorbers
use Energy Absorption

Energy Absorption
1880 1222 904 45 906 1637 789
1990 2092 2094 755 1426 2097
2352 2354 905 1636
2355

Energy Dissipation
902 103 2184 1195
2192 1873 1805

Abstract												
Numbers: 1-217 218-483 484-719 720-886 887-1187 1188-1402 1403-1574 1575-1798 1800-2046 2047-2289 2290-2504 2505-2891												
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Failure Detection
2471 2402 2403 2404 696 2018 2289
2444

Fan Blades
950 1533

Fan Noise
1581 2047
1861 2297

Fans
1580 951 1413 1174 525 226 517 68
1581 1533 1414 875 526 727
1811 1853 1784 1415 726 1427
1957
2567

Fast Fourier Transform
2012 674 526 69
1364 2086 1089

Fast Fourier Transformation
use Fast Fourier Transform

Fatigue Life
470 1 12 163 64 165 326 227 238 599
600 41 1342 1083 164 265 836 317 258 659
660 191 1992 1163 224 285 856 327 1188 1219
1200 211 2222 1343 834 895 1186 1187 1218 1719
1440 321 1603 894 1085 1566 1617 1298 2109
1660 481 1993 1084 1625 2016 1717 1348 2439
1720 661 2303 1524 1645 2636 1787 1438 2519
1870 791 2373 1544 1795 1837 1718 2639
2220 1111 2643 1564 2635 2077 1788
2440 1341 1834 2107 1938
2460 1371 1994 2117 2368
1871 2304 2367 2438
1991 2644 2427 2618
2221 2637 2638

Fatigue (Materials)
1530 162 835 659
2642

Fatigue Strength
use Fatigue Life

Fatigue Tests
680 2441 1083 1084 205 236 237 438 1189
2641 2343 1344 325 916 327 2369
2374 835 1346 437
1085 1546 1347

(cont'd)

Fatigue Tests (continued)
1185
1345
1525
2375

Feedback Control
1116

Fiber Composites
340 612 2354 2355 2297 88 2149
1342 2407 998 2439

Fiberglass
2183

Fiberscopes
176

Field Test Data
1630 1204

Filters
2460 1731 2002 2003 179
2471 2472

Finite Difference Technique
862 123 84 2155 1496 2227 939
1642 1506
1656

Finite Difference Theory
use Finite Difference Technique

Finite Displacement Method
963 1375

Finite Element Technique
250 1 142 343 4 365 46 37 8 99
460 361 362 353 114 455 196 77 68 459
730 1131 492 403 364 505 246 1277 398 469
750 1381 722 453 454 855 346 1387 408 539
760 1711 732 663 474 1005 556 1477 418 749
780 2321 862 783 884 1375 706 1687 458 969
860 2491 892 813 974 1595 736 1937 878 989
890 2551 1132 843 984 1935 776 2127 928 1119
1010 1642 1033 1484 2025 1056 2177 1438 1219
1130 1672 1293 1914 2275 1086 2377 1478 1269
1150 2082 1393 2274 2555 1126 2058 1279
1330 2102 1463 2294 2675 1506 2088 1909
1410 2282 1963 2504 1826 2128 1929
1950 2512 2053 2604 2126 2138 1979
1960 2682 2283 2166 2148 2019

(cont'd)

Abstract

Numbers: 1-217 218-483 484-719 720-886 887-1187 1188-1402 1403-1574 1575-1799 1800-2048 2049-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Finite Element Technique (continued)

2080 2503 2196 2168 2069
2190 2673 2386 2188 2219
2380 2683 2258 2419
2490 2478
2590

Finite Strip Method

983 616 1257 558

Flexibility Coefficients

2042 1133 1137 2108
2377

Flexible Couplings

510 333 794

Flexible Foundations

724 1946 1828 2049

Flexible Rotors

500 491 2662 223 2474 1115 486 487 2668 499
700 701 493 1365 1366 1807 1409
1170 1741 723 1405 1406 2667 2669
2531 1173 1565 2666
2661 1743
1813

Flexible Shafts

2296 2509

Flexural Response

2101 333 1889

Flexural Stiffness

1060 1405

Flexural Vibration

100 91 492 1663 94 225 986 1247 618 109
340 111 1082 1903 1014 325 1456 1337 1168 1249
1250 341 1532 2103 1264 625 1926 1577 1178 1259
1660 351 1852 2153 1924 975 2386 1927 1258 2399
1720 611 1932 2154 1655 2606 1987 1268
1001 2332 2214 1935 2157 1338
1261 2384 2155
1671 2424 2605
1941
2161
2411

Flexural Waves

970 2151 1272 944 2455 2609
2162 1014

Flight Tests

1727

Flight Vehicle Equipment Response

2241

Flight Vehicles

560 1085 929
2235

Floating Bodies

use Floating Structures

Floating Ice

1854

Floating Ring Journal Bearings

73 2577

Floating Structures

826

Floors

2621 1823 385 1038
1635

Flow-Induced Excitation

use Fluid-Induced Excitation

Flow-Induced Vibration

use Fluid-Induced Excitation

Fluid Amplifiers

1075

Fluid Couplings

1677

Fluid Damping

use Viscous Damping

Fluid Drives

10 546

Fluid-Filled Containers

790 411 783 374 1275 1946 1277 1018 1279
1010 1951 1673 784 1675 1947 1028 1949
1950 2481 2613 1674 1945 2347 1278
2160 2673 2348

Fluid-Film Bearings

580 581 1892 315 1406 79
1740 761 509
869

Abstract

Numbers: 1-217 218-483 484-719 720-888 887-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Fluid-Induced Excitation

130	131	132	23	134	95	96	127	158	129
740	391	262	133	374	485	116	377	208	349
770	791	572	373	604	1275	346	1267	378	519
990	951	922	503	1024	1795	606	1427	488	759
1200	971	992	623	1254	2415	716	1737	518	939
1490	991	1602	653	1764		736	1787	948	979
2170	1021	1722	993	1834		1026	1947	1288	1509
	1031	1912	2593	1944		1496	2417	1788	2169
	1491	2072	2413	2364		1676	2617	1808	
	1551	2142	2613			1686			
	1661					1836			
	1711					1896			
	1841					2116			
	2051					2146			
	2131					2416			

Fluid-Induced Vibrations use Fluid-Induced Excitation

Fluid Mechanics

2478

Fluids

2452 1675 2347

Flutter

950	881	92	43	404	415	66	1137	158	759
1620	961	752	1153		2275	286	2037	938	769
1790	1621	872	1533		2345	726	2567	2038	929
2040	1791	1152	1623			1526			1139
2360	2041	1452				1666			1619
	2101	1792				2086			1869
		1902				2516			1889
		2102				2556			2039

Flywheels

1639

Foams

942 1704 1637

Follower Forces

601 92 1334 1526
1261

Footings

250

Force Apportioning Method

420

Force Coefficients

2052 1477 1478

Force Generators

2243 2244

Force Measurement

1092

Force Summation Method

1756

Forced Response Strain Energy Method

1386

Forced Vibration

871 342 83 504 1535 1068 2399
492 1003 554
1772 1063
1253

Forcing Function

2090

Fossil Power Plants

890 1811 1416 1287 2548
1427

Foundation Excitation

use Base Excitation

Foundations

220 253 1804 1805 526 1827 1828 1829
1180 1825 536 2527 2529
1740 1936
1830
2530

Four Bar Mechanisms

2491

Fourier Analysis

973 354 1728 2319
1924 2138
2658

Fourier Series

2148

Fourier Techniques

use Fourier Analysis

Fourier Transformation

430 2191 992 1383 2146 818 429
2442 1448

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2891

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

- H -												
Half-Plane												
Half-Space												
	1044											
Hamiltonian Principle												
	2144											
Hammers												
Handbooks												
use Manuals and Handbooks												
Hand Tools												
	2534											
Harbors												
	2314											
Hardened Installations												
1421 1252												
Hardened Structures												
use Hardened Installations												
Harmonic Analysis												
980 2141												
990												
Harmonic Balance Method												
Harmonic Excitation												
410 1331 412 413 414 1885 1256 437 1918 89												
1080 1691 992 1923 784 2435 1696 727 2598 779												
2100 1821 1986												
2361												
Harmonic Response												
1272 1403 1594												
Harmonic Waves												
Head (Anatomy)												
1573												
Heat Exchangers												
130 131 132 133 2414												
1020 1021 2412 2413												
2170												
Heat Generation												
1290 1171												
Heat Shields												
Heat Transfer												
1020												
Heaving												
770												
Helical Gears												
1240 762												
1650												
Helical Springs												
Helicoidal Membranes												
283												
Helicopter Blades												
use Propeller Blades												
Helicopter Engines												
1523 705												
Helicopter Noise												
940 1633 1154 1226 1228 1389												
1863 1388												
Helicopter Rotors												
use Helicopters and Rotors												
Helicopter Vibration												
291 292 293 284 1226												
553 1874												
Helicopters												
2 953 554 1175 46 1177 1228 939												
1152 1153 874 1225 1176 1227 1388 1229												
1652 2253 954 1585 1226 1389												
2102 1154 1635 1646 2559												
1584												
1624												
Helmholtz Resonators												
1027 1028												
Abstract												
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691												
Volume 13												
Issue: 1 2 3 4 5 6 7 8 9 10 11 12												

Hertzian Contact
2112

High Frequencies
2456 2197

High Frequency Excitation
2570 822

High Frequency Response
107

High Speed Transportation Systems
918 1849

Hilbert Transforms
1124

Hill Equation
1553 2027

Hitches
use Drawbars

Hole-Containing Media
1052 984 356 998
1234
2024

Holes
1052

Holographic Techniques
1090 171 172 1926 447
1730 1091 1312 2016 2647
2156

Honeycomb Structures
755

Hoses
1025 1027

Housings
331
1181

Hovercraft
use Ground Effect Machines

Hulls
991

Human Hand
861 297

Human Head
use Head (Anatomy)

Human Organs
use Organs (Biological)

Human Response
50 51 52 53 754 935 1876 537 568 49
150 861 912 903 934 2046 817 1468 569
570 911 1232 1233 1444 1877 1878 689
1570 941 1632 1573 1469
1630 1231 2622 1633 1629
2350 1631 1863 1879
2351 2349

Human Tolerance
155

Hunting Motion
20 921 273 2074
1850

Hydraulic Equipment
10 1224 1025 9

Hydraulic Systems
305 546 1027 1598
1026 1147

Hydraulic Valves
1485

Hydrodynamic Bearings
1482

Hydrodynamic Damping
524 356

Hydrodynamic Excitation
770 71 1912 1513 1254 1595 1636 927 418 1499
1210 2072 1954 1856 1597 2188
2380 2314 2066 2067 2578
2317

Hydrofoil Craft
2081 404 279

Hydrophones
1722 1735 2646
2495

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Hydrostatic Bearings
300

318
1238

Hysteretic Damping
2192
2612

425 1066 1758 2199
655
1495

- 1 -

Ice

1854

Impact Dampers
use Shock Absorbers

Impact Force

2273

818

Impact Noise

2184

Impact Response

1350 611 152 403 574 35 357 58 359
2081 1072 563 974 355 467 68 2179
1823 1934 665 757 108 2589
2125 847 958
2145 2387 1238
2235 2408

Impact Shock

636

Impact Testing
use Impact Tests

Impact Tests

2583

1516 837

Impedance Technique

1571 1513
2493

1499

Impellers

1 503

877 488

Impulse Intensity

2432

Induction Motors

1360 1693

699

Industrial Facilities

1391 392 813 395 816 247 628 629
2431 2623 815 2006 887 2548 1879
1515 907
1975

Industrial Noise

use Industrial Facilities and Noise Generation

Inertial Forces

2395

Influence Coefficient Matrix

use Influence Coefficient Method

Influence Coefficient Method

700 871 2474 1365
2020 1901
2661

Initial Deformation Effects

1270 361 762 1264 2398 339

Initial Value Problems

use Boundary Value Problems

Instrumentation

1748

Instrumentation Response

1357

Instruments

use Instrumentation

Integral Equations

1560 1552 1373 194 1135 97 848
2270 1772 2264 847

Integration

1555

Interaction: Ice-Structure

1604

Interaction: Rail-Vehicle

1203 206 748

Interaction: Rail-Wheel

20 691 272 183 34 65 207 2099
690 921 1202 2553 274 945 1437

(cont'd)

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Interaction: Rail-Wheel (continued)
 920 1852 1434 1355
 2332 1435

Interaction: Rotor-Casing
 2508

Interaction: Rotor-Foundation
 2530 2527 2528 2529

Interaction: Rotor-Stator
 281 39

Interaction: Shiphull-Machinery
 37 928

Interaction: Shock Waves - Boundary Layer
 1054

Interaction: Soil-Structure
 400 252 253 2504 655 1826 637 468 29
 732 793 885 1936 1827 1828 819
 1982 2043 1785 2286 2628 1359
 2313 1779

Interaction: Solid-Fluid
 1723 1677

Interaction: Structure-Fluid
 390 411 362 263 264 365 196 1067 408 269
 2390 2481 842 363 364 375 736 2257 418 369
 2410 2541 922 803 424 2165 2256 2317 1018 469
 2611 1602 2123 544 2255 2316 1918 2409
 2673 2254 2285 2188
 2258

Interaction: Structure-Medium
 2258

Interaction: Vehicle-Guideway
 918

Interaction: Vehicle-Terrain
 902 903 275

Interaction: Vehicle-Tire
 578

Interaction: Wheel-Pavement
 290 441 44 288 289

Interface: Solid-Fluid
 1698

Interface: Solid-Solid
 1303 2446 848

Interferometers
 171

Interferometric Techniques
 1090 2462 66 447 2459
 1926
 2156

Interior Noise
 940 2321 1213 2324 2555 936 118
 2470 2318

Internal Combustion Engines
 1884 2457

Internal Damping
 1404 2207 358
 768
 2518

Inverse Variational Principle
 1145

Isolation
 303 2677

Isolators
 566 2097 2098
 756
 2096

Iteration
 1561 1562 2054 1385 2496
 2495

- J -

Jet Engines
 281 212 1413 1414 1505 1447 1449
 1611 2567

Jet Noise
 1450 1211 1613 1966 1449
 1860 1861

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2299 2299-2504 2505-2991

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Joints (Junctions) 601 1653 184 335 2376 597 598 2589 761 2373 794 1255 2177 958 1991 1244 1895 2377 2588 2374 2115 2375	Large Amplitudes 2411 1282 1935 2386 1929 2149
Journal Bearings 760 2581 72 73 74 75 76 587 318 69 1480 2582 493 2584 585 486 2527 588 499 2580 1643 2365 586 2577 2108 509 2583 2505 2366 2578 2109 2579	Lasers 2462 2187
Lateral Response 2331 1205 2537 2189	Lateral Vibration 521 2122 484 5 1576 2381 1904 945 1025
Lathes 2058	Launch Vehicles 858
Launchers 48	Launching Response 557 559
Lawn Mowers 814	Lawn Mowers 814
Layered Damping 2384 1336 2219	Layered Materials 1250 1341 152 413 104 1265 1016 387 998 999 1310 1511 412 533 414 1305 2026 1937 1039 2031 1682 1493 2126 2407 1269 2181 1563 1929 1923 2439 2433
Leading Edges 404	Leaf Springs 61
Least Favorable Response Method 2249	Least Squares Method 850 202 445 639 852 1365 859

- L -

Laboratory Test Data 1630 1604 1488	Laminates use Layered Materials
Lagrange Equations 988	Lanczos Method 1663
Lamb Waves 1701	Landing Fields use Aircraft Landing Areas
Landing Gear 1462 947 1227	Landing Impact use Landing and Impact Shock
Landing Shock use Landing and Impact Shock	Landing Simulation use Landing and Simulation
Laplace Transformation 1771 192 2024 1906 2298 199 2226	Landing Simulation use Landing and Simulation

Abstract Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691	Volume 13 Issue: 1 2 3 4 5 6 7 8 9 10 11 12
--	---

Liapunov's Method use Lyapunov Functions										Loosening				1694		958	
Life Line Systems										Loss Factor							
804 1785 2627 798 1594										1100							
Limit Analysis										Low Frequencies							
422 125										600 1231 562 1263 1036 2507 1309							
Line Source Excitation										1880 2651 2570							
993										Lubrication							
Linear Analysis										70 2571 1813 2114 1895 1237 2108							
use Linear Theories										2110 2113 2594							
Linear Damping										Lumped Mass Method							
use Viscous Damping										use Lumped Parameter Method							
Linear Systems										Lumped Parameter Method							
160 1561 472 423 464 405 1156 457 2208										970 1913 1755 1376 767 2329							
1070 2022 1333 1376										2380 2503 1757 2599							
2480 1773										Lyapunov's Method							
Linear Theories										2480 844 845 1377							
1801 2432 375 1056 1598																	
1395 2406 1758																	
Linings																	
1114 2065 1287 1678										- M -							
Linkages																	
2590 601 1484 335 1655										Machine Diagnostics							
Liquefaction										use Diagnostic Techniques							
733										Machine Elements							
Liquid Filled Containers										use Machinery Components							
use Fluid Filled Containers										Machine Foundations							
Liquid Propellant Rocket Engines										1830 535 2539							
1466 858										Machine Noise							
Locomotives										use Machinery Noise							
1202 1203 2325 746										Machine Tools							
Longitudinal Response										880 231 232 2293 756 2307 1238 9							
1025 1455										1400 531 1402 2306 2377 1418 319							
Longitudinal Vibration										1401 1182 2376 2058 2059							
1831 1462 2597 1658										Machinery							
Abstract										191							
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691										1361							
Volume 13										2281							
Issue: 1 2 3 4 5 6 7 8 9 10 11 12																	

Abstract												
Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Measurement Techniques (continued)

2320 2301 2232 2523 1734 2456 2228 2359
2360 2573 2004 2248
2420 2648
2650

Measuring Instrumentation use Measuring Instruments

Measuring Instruments

670 2001 1092 303 674 435 436 177 668 1099
2000 2461 1352 1093 1094 1095 666 1097 1098 1529
2681 1732 1003 1354 1355 1356 1727 1528 1999
2062 1533 1724 1725 1726 1997 1998 2459
2672 2645 1996 2008
2248
2458

Measurement Techniques use Measurement Techniques

Mechanical Admittance

981 1276

Mechanical Drives

2303 2054 1587 2688
2293 2304 1647

Mechanical Elements

856

Mechanical Impedance

610 621 682 1103 2344 2096 767 878
1400 681 1362 1483 2437
1401 1402 2463
1271

Mechanical Properties 1092

Mechanical Reliability use Reliability

Mechanical Systems

840 1555

Mechanisms

2491 2272 1183 1556
2492 2486

Membranes

use Membranes (Structural Members)

Membranes (Structural Members)

2142 2393 454 2025 1917 2138

Metal Working

2060 1818
2588

Metals

2440 645 2636

Method of Characteristics

2225 1496

Method of Harmonic Linearization

380

Method of Initial Functions

1260 102 987

Method of R-Functions

2489

Method of Steepest Descent

use Steepest Descent Method

Method of Stochastic Averaging

2033 1066

Method of Weighted Residuals

1959

Mindlin Theory

983 1268

Mines (Excavations)

641 642 2008 1469
2311 2639

Minicomputers

752

Minimax Technique

1320 2666

Mining Equipment

627

Missile Launchers

2118

Missile Launching

2118

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1674 1675-1799 1800-2046 2047-2289 2290-2504 2505-2801

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Missile Silos											Mode Shapes											
1252											110	11	982	63	1924	985	986	337	558	1299		
											350	1661	1262	223		1005	1006	417	878	1559		
Missiles											1010	1831	1332	323		1905	1246	1247	1118	2159		
2560	294	415	576	567	1628					2150	1931	1672	1193		1925	1776	1657	1428	2539			
	2238									2510	2091	1253			2115	1926	1917	1678				
										2361		1663			2266		1848					
Mixed Element Technique												2393					1898					
982												2523					2058					
																	2648					
Mobility Functions										Model Testing												
										540	541	543			757		2539					
Mobility Method															1583							
1140	2232	2493				1729																
Modal Analysis										Model Tests					use Model Testing							
2230	461	322	203	534	405	6	1607	678	679													
	2681	472	1374		1425	1136	2207	1778	1069													
	2612				1755	1156	2267	2268	1209													
						1756		2299							2269							
								2509														
Modal Balancing Technique										Moment Coefficients					1477 1478							
2661	2474		1365																			
Modal Constraint Method										Monitoring Techniques												
2483										190	191	2472		704	695	676	447	188	189			
										1370	211	2672		1544	705	706	707	448	449			
										1750	1371			1744	1545	1546	1117	718	839			
Modal Damping										2670	1751				1745	1746	1547	1368	1369			
	1205					1428				2671					2476	1747	1568	1749				
																1748						
Modal Densities										Monte Carlo Method												
1100															1774	1656						
Modal Superposition Method															2276							
	821	782	843	2274	2136		1009															
	822																					
Modal Synthesis										Moorings					2335		607					
2501						196				1069												
Modal Tests										Motorcycles					754 1205		1848					
															1204							
	534					2089																
	1104																					
Mode Approximation Technique										Motor Vehicle Engines					73							
	1324 1315																					
Mode Displacement Method										Motor Vehicle Noise					2551 1842 913 914 1165							
	1756														1164							
Mode Modification Method										Motor Vehicles					1634		1846 1607					
560																						
Abstract																						
Numbers:	1-217	218-483	484-719	720-886	887-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691										
Volume 13																						
Issue:	1	2	3	4	5	6	7	8	9	10	11	12										

Motors
1360 161 1042 1693 1694 2525 2526 528
1092 2524

Mountings
5562 756 1177
2526

Moving Loads
730 2191 12 1854 775 1906 2127 8 1659
1820 1002 1984 2385 2397 1588 2129
1890 1682 1668
2122 2128
2258
2418

Mufflers
1470 1471 1472 393 304 1397
1883 1234
1884

Multibeam Systems
1021 373 344 345 377 378
1288

Multidegree of Freedom Structures
use Multidegree of Freedom Systems

Multidegree of Freedom Systems
820 1761 572 1713 1524 2496 898 409
2300 2493 1714 829

Multifrequency Testing Techniques
2240

Multiplane Balancing Technique
1741

Multipocket Bearings
1644

Multipole Analysis
141

Multistorey Buildings
1990 731 1822 2063 2536
1081 2392
1921

Musical Instruments
2648

- N -

Nastran (Computer Programs)
1150 1151 364 2275 556 2037 2038 2039
2040 2321
2590

Natural Frequencies
110 11 92 63 4 765 596 87 38 109
350 101 112 113 84 985 986 337 528 1249
1000 1261 982 223 114 1005 1006 417 558 1299
1010 1661 1262 323 124 1205 1246 867 878 1549
1800 1831 1662 1193 234 1905 1776 987 1028 1559
1910 1931 1672 1913 384 1925 1926 1257 1118 2159
1940 2061 1922 1943 454 2115 2266 1287 1178 2269
2150 2361 2082 2393 1904 2386 1657 1278 2239
2510 2132 2483 1924 1917 1428 2599
2202 2523 2054 2137 1678
2294 2197 1888
2484 2347 1898
2494 2058
2648

Natural Vibrations
492 1937

Newmark Method
1135

Noise Barriers
810 811 1882 633 2624 55 146 147 808 149
1973 2545 807 1308 809
919

Noise Control
use Noise Reduction

Noise Generation
2290 311 82 283 394 135 226 137 328 19
2340 2051 392 813 395 816 887 628 329
2551 812 1033 555 926 1307 1418 269
1202 1413 815 1196 1487 1568 1179
1512 2323 1225 1486 2307 1818 1469
1952 2333 1586 2547 1509
2332 2623 1879

Noise-Induced Excitation
1497

Noise Measurement
670 1451 1202 143 144 815 1446 1877 908 169
1810 1531 1352 753 814 1215 1616 2007 1088 909

(cont'd)

Abstract												
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2891												
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Noise Measurement (continued)
 2320 2341 1732 1413 914 1445 1976 1858
 2342 1443 1204 1505 2006
 1214 2046
 1414 2546
 1464
 1574
 2084
 2324

Noise Meters
 use Sound Level Meters

Noise Prediction
 1390 931 932 143 1154 1155 1206 1877 1228
 1391 1212 853 1864 1505 1216 1858
 1612 2073 2184 2555 2546

Noise Propagation
 use Sound Propagation

Noise Reduction
 520 281 282 13 14 55 146 147 228 9
 530 331 302 393 304 245 546 247 538 19
 630 631 392 533 314 525 816 627 628 39
 910 1181 602 613 564 815 866 887 1958 149
 940 1211 622 813 1174 915 1026 1027 2318 529
 1420 1471 632 943 1184 1025 1786 1207 2338 629
 1450 1861 812 1433 1244 1035 2056 1217 2548 879
 1470 2591 1032 1613 1614 1445 1397 919
 1780 1242 1703 1704 1515 1447 1439
 2690 1432 1843 1784 1955 1467 1449
 1472 1863 1844 1975 1607 1859
 1512 1883 1974 2055 2297
 1842 1973 2174 2085 2337
 1862 2563 2184 2305 2677
 1972 2534
 2182 2624
 2552

Noise Shielding
 1613 1614
 1703

Noise Source Identification
 330 2431 82 2233 694 2325 1306 137 2658 2319
 1050 1542 1957
 2470

Noise Tolerance
 50 911 913 934 935 49
 941 1283
 1231

Noise Transmission
 1294 907 98
 108
 2338

Nomographs
 2632 2358

Noncontacting Probes
 use Proximity Probes

Nondestructive Testing
 use Nondestructive Tests

Nondestructive Tests
 440 441 1362 1304 1736 1107 1348
 660 2012 2444 1796 1797 1798
 2467

Nonholonomic Systems
 2273 1557

Nonlinear Analysis
 use Nonlinear Theories

Nonlinear Damping
 1105

Nonlinear Programming
 1543

Nonlinear Response
 361 1064 965 966 968 969
 2484 1065 1766 2069

Nonlinear Structures
 2189

Nonlinear Systems
 1320 1331 192 403 464 415 406 1377 828 409
 1760 1551 402 1773 1074 1325 2276 1907 1058
 1770 1561 1072 2023 1334 2205 2387
 1782 2033
 2302

Nonlinear Theories
 230 1281 22 463 4 2265 1986 7 198 1199
 410 2411 2442 1043 864 2206 1387 1598 2509
 1134 2278

Nonlinear Vibrations
 1330 1492 1763 1495 2166 647
 1933

Abstract												
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2681												
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Optimization	Panels											
880 1141 232 903 854 846 859	980 1041 1792 2343 774 285 246 1667 98 979											
1411 1242 1133 1874 1386 1789	1790 1791 2142 1034 995 1666 2177 978 1919											
1881 2214 2556	1920 1921 2602 1294 1255 1218 2139											
	1990 2141 1918											
Optimum Control Theory	2140											
1634	2650											
Optimum Damping	Parameter Identification Technique											
1875	850 201 202 203 244 465 306 1137 1138 679											
	2550 1101 422 1563 694 595 316 1867 2278 2279											
Optimum Design	2580 1221 1773 1774 1775 1806 2277 2559											
1320 2281 153 1454 975 1318	2583											
1900 2093 1145 2238												
2680	Parametric Excitation											
	1120 2021 452 1073 2194 1395 1436 2517											
	1240 2302 1763 2625 2516											
Orthotropic Plates	1550											
use Orthotropism and Plates	1650											
Orthotropism	Parametric Resonance											
1670 1922 1263 104 115 2396 1928 2399	2130 501 1776											
	2131											
	2391											
Oscillating Conveyors	Parametric Response											
2308	780 1023 1094 1095 1946 897 898											
	2515											
Oscillation	Parametric Vibration											
451 562 1075	650 501 1065 2027											
1141 1042 1535												
1551 2482	Passive Isolation											
	2565											
Oscillators												
1121 1062 1074 2435 827												
	Pasternak Foundations											
2032 2434												
2652	2397 2129											
Overdamping	Pavements											
2208	470 441 1107											
	Penalty Technique											
	453											
	Pendulums											
	954 1769											
	Penetration											
	644 645 646 2198											
Packaging												
635	Periodic Excitation											
	1070 352 723 2654 966 227 2358 1059											
Packaging Materials	1560 2612 1013 1626 1237 1829											
	1710 1946 1667 2029											
574 757	2607 2449											
1474												
Abstract												
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1788 1800-2046 2047-2288 2290-2504 2505-2681												
Volume 13												
Issue: 1 2 3 4 5 6 7 8 9 10 11 12												

Periodic Response

550 2231 252 2143 204 406 2577 358 89
2493 1136 768 1489
1328 2129
1378 2379
2378

Periodic Structures

990 992 993 1068 1379
1120 1023 1759
1073 1909
2203

Perturbation Theory

2481 452 963 2185 896 357 78 1329
2442 1377 1128
2257 1328

Phase Effects

1720

Phase Velocity

1507

Photoelastic Analysis

1350 1372 2223 2224 2016

Photographic Techniques

2554

Piers

1190

Piezoelectric Transducers

173

1998

Piezoelectricity

1965

Pile Drivers

2547

Pile Driving

886

Pile Foundations

732

536

Pile Structures

884 885 1836 1908

Pipe Resonators

391

1499

Pipe Whip

1393

2619

Pipeline Systems

use Pipelines

Pipelines

370 371 1022 243 794 255 26 797 368 799
800 2642 253 1024 795 796 1687 798 1149
1983 1504 1495 896 2417 1688 2419
1785 2418

Pipes (Tubes)

140 621 622 793 1284 375 786 127 128 789
790 781 792 1393 1954 785 1286 787 208 1499
1500 1501 1952 1503 2414 1285 1796 1287 788 1689
2171 1953 1505 1896 1497 1018 2609
2615 2416 1797 1498
2616 1798
2618

Piping Systems

791 372 393 1544 376 367 258 369
801 802 623 2614 1686 1907 379
1502 803 2619
2042 1283
2172

Plain Bearings

2109

Plane Mechanisms

2680

Plastics

147

Plate Girders

1185 1186 1188 1189

Plates

100 101 102 103 104 105 106 107 108 99
110 111 112 113 114 115 116 117 358 109
350 351 352 353 354 355 356 237 618 349
450 981 982 563 434 615 616 357 978 469
990 991 992 613 614 625 776 617 988 539
1000 1001 1052 983 644 775 986 777 998 619
1100 1261 1262 993 984 985 996 987 1268 989
1150 1271 1272 1003 1004 1265 1256 997 1668 999
1260 1671 1672 1263 1034 1765 1266 1257 1928 1029
1270 1691 1922 1273 1264 1925 1926 1267 1938 1049
1670 1991 1932 1923 1294 1935 2146 1667 2158 1259

(cont'd)

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Plates (continued)										Power Transmission Systems									
2150	2151	2152	1933	1924	2145	2156	1917	2398	1269	230	831					1417		879	
2400	2401	2332	2153	1934	2155	2396	1927	2448	1669	530	1181					1587			
		2402	2403	1984	2395	2426	1937		1929										
			2453	2144	2405	2606	2147		2149										
			2603	2294	2605		2157		2279							806			
				2154			2397		2399										
				2404					2489										
				2604															

Abstract

Numbers: 1-217 218-483 484-719 720-886 887-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Propellant Tanks

2013

Propeller Blades

1720 311 1152 953 524 1175 2557 939
2340 2102 1153 874 1585 1229
1463 954
1583 1624
2344

Propeller Induced Excitation

1532 116

Propeller Noise

931 143 1615 1616
2341 283
1863

Propellers

1720 931 555 1576 2557

Proximity Probes

1726 2457 2458
2456

Pulleys

2300

Pulse Excitation

1270 801 612 2403 374 1315 1556 1687 2298 1669
1670 1762 1324 2396 1919
1680 2402 1654
1900 2404
2424

Pulse Test Method

2011 2242

Pumping

804

Pumps

10 591 582 3 504 515 1026 587 228 9
520 2291 602 473 1354 1416 508 519
1582 2533 518 529
2052 528 839
1108 1179
1538
1738

- Q -

Quadratic Damping

2095

Quartz Resonators

107

Quasilinearization Technique

850 859

- R -

Racks

1916

Radiation Efficiency Method

1047

Rail Transportation

917

Railroad Cars

690 691 183 34 35 206 207 1438 59
1850 921 273 64 65 1436 1437 1249
2653 1434 1435
2564

Railroad Tracks

2090 1852 2075 256 1659

Railroad Trains

20 1851 715 549
2371 1849

Railroad Transportation

use Rail Transportation

Railroad Vehicles

use Railroad Trains

Rails

use Railroad Tracks

Railway Vehicles

use Railroad Trains

Abstract

Numbers: 1-217 218-483 484-719 720-888 889-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Rotors (continued)				Scaling			
2360	2511	2592	2523	2666	2669	2250	183 634 925 1737
2510	2521	2662	2593				1604
2530	2531		2633			Screws	
2660	2661		2663			600	599
Rotors (Machine Elements)				Seals			
use Rotors						1582 603 604 605 336 1537 2118 959	
Rubber						2592 2593 764 2585 606 1897	
use Elastomers						2594 2595 716 2117	
Runway Roughness						2106	
290	1461			288	289	2596	
				Seat Belts			
						181 1632	2327
				Seismic Analysis			
						1590 261 882 1283 1255 1198 1779	
						1601 1502 2383 1915	
						2171 2312	
				Seismic Barriers			
							2068
Safety Belts				Seismic Design			
use Seat Belts						240 241 792 153 384 735 16 17 248 379	
Safety Restraint Systems						1320 261 1422 253 794 1195 216 1167 468 479	
2330	181	1222	277			2601 2192 1143 1144 1825 376 1777 1158 1399	
		1632	2327			2691 2193 1835 1166 2317 1318 2309	
Sand						2195 1916 1398	
			2466 1197				
Sandwich Laminates				Seismic Detectors			
use Sandwich Structures							2078
Sandwich Panels				Seismic Excitation			
use Panels and Sandwich Structures						250 821 242 1983 154 1705 416 737 1158 1279	
Sandwich Structures						1661 892 2383 684 2135 736 2097 1498 2189	
	341	2602	2395	1928	2139	2621 1072 2433 1144 796 1948	
	2141			2219		1962 2064 2066 2098	
						2062 2674 2178	
SAP (Computer Programs)				Seismic Isolation			
		813				60	2097 2098
Satellite Antennas				Seismic Response			
use Spacecraft Antennas						30 251 372 773 24 15 386 27 28 29	
Satellites						260 771 772 783 344 25 806 257 368 239	
			1128			370 891 782 793 764 545 1706 267 688 259	
						400 2311 822 883 804 795 1916 847 798 399	
						800 2531 1022 893 824 825 2136 2177 1038 799	
						820 2392 1193 884 1385 1518 889	
							(cont'd)

Abstract

Numbers: 1-217 218-483 484-719 720-888 889-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2891

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Seismic Response (continued)											
890	1423	1424	1595		2628	1099					
2070	1823	2134	1785			2419					
2560	2193	2194	1825								
		2614									
Seismic Response Spectra											
		194									
Seismic Waves											
2540			255		1517	1158	1319				
					2067	2068					
					2628						
Self-Excited Vibrations											
490	561	1172	1063		1295	516	1327		489		
1210	1481	2102	2213		1485	1286			1329		
1710									1479		
2200									1689		
Semiactive Isolation											
		2564	2565								
Semitrailers											
						1278					
Series (Mathematical)											
		2132									
Shading Techniques											
		1534									
Shafts											
1410	2521	1162	1403	1404	2295	486		868	1169		
1720		1802	2253	1564	2525	2296		1168	2519		
1800		2522		2524				2688	2579		
2520				2594							
Shafts (Machine Elements)											
720	721	512	1173	484	5	6	7	708	219		
1170	831		1543		225	1366	857	2048	669		
1580	1171				475	1576	1807				
	1181					1405					
	1411					1575					
	1741										
Shakedown Theorem											
								1349			
Shakers											
	2242				1106	1197		2649			
Shear Deformation Effects											
use Transverse Shear Deformation Effects											
									576		

Shear Waves
1270 1699

Shells
120 121 122 123 124 125 126 117 118 119
360 361 362 363 364 365 366 617 368 259
620 1011 1012 973 1014 855 426 1007 1008 359
1280 1041 1282 1013 1684 865 1016 1017 1498 469
1680 1281 1682 1673 1944 1005 1276 1677 1678 1009
1940 1681 1942 1683 2164 1015 1676 2167 2168 1679
2160 1941 2162 1943 2254 1945 2166 2407 2408 1939
2390 1951 2612 2163 2145 2406 2607 2608 2159
2410 2161 2613 2165 2618 2409
2610 2361 2609
2611

Shells of Revolution
1281
1951

Ship Hulls
922 863 116 37 2198 1609
1532 973

Ship Vibration
750 1532 863 1608 749
923

Shipboard Equipment Response
2080 2211 924 37 2079

Shipping Containers
635 2076 467
917

Ships
70 552 704 925 926 37 38 279
1162 2334 1855 1856 927 278 2629
2335 928
2288

Shock Absorbers
2092 1473 214 575 299
2095

Shock Absorption
26

Shock Excitation
471

Shock Isolation
576

Abstract
Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2681

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Sonic Fatigue Resistant Structures	1218	Sound Waves	620 381 2452	1514 1505 1696 1037 138 1969
			1860 1611	1695 1047 1308 2179
Sound Attenuation			1920 2611	1955 1697 1448
610 1292 633 1214			2180	1698
2422			2410	1968
Sound Detectors	1735		2430	2028
		Spacecraft	210 411 1332	294 295 296 1627 48 559
Sound Generation			560 421 1402	1465 1666 2347 1568 1079
2620 2362	2428		1400 1401 1582	1875 1716 2088 2089
Sound Insulation			2291 1672	2346 2348
use Acoustic Insulation		Spacecraft Antennas		
Sound Level Meters			94	
1732		Spacecraft Components	561 562 2013	566 557 558
Sound Measurement				
1311	1309	Space Shuttles	1230 561 562	564 565 566 557 508 1549
	2459		2291 1582	1466 558
Sound Power Levels		Specifications		1186 2287 2288 2289
	314 2325 2006			2438
	1704			
Sound Pressure Levels		Speckle Metrology Techniques		
	1013 1196		434 2647	
Sound Pressures				
	1695	Spectral Analysis		
		use Spectrum Analysis		
Sound Propagation				
1310 1581 1812 2173 614	136 1857 2179	Spectral Energy Distribution Techniques	160 681 682	194 1385 2206 1628
1610 2421 2423 624	1036 2547 2339		1690	
1860	1506 2687			
2420		Spectrum Analysis		
Sound Reflection			40 2071 2382 2233 464 675 2486 2657 448 1179	
630	1698		2230 2231 2443 2444 2656 1138	
Sound Transducers			2580 2614 1518	
	56			1738
	2646	Spectrum Analyzers	432 674 676 137 1728	
Sound Transmission				
630 621 1032 933 104 1015 106	128 349	Spheres		1695 427 2179
1960 1031 1292 634 1465 1016	1698 1919			2437
1971 2602 2535 1956	1958 1959			
	2426	Spherical Bearings	320 761	77
Sound Transmission Loss				
2650 613 1294 2175				

Abstract

Numbers: 1-217 218-483 484-719 720-886 887-1187 1188-1402 1403-1574 1575-1799 1800-2048 2049-2289 2290-2504 2505-2891

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Spherical Shells
122 123 1684 1945 366 117 1008 1009
1683 1007 2408 1939
2613

Spherical Waves
1700 1053

Spindles
813 2058

Spring Constants
955 316
606

Spring-Mass Systems
use Mass-Spring Systems

Springs
62 1235 2358
1475

Springs (Elastic)
1071 593 306 307

Spur Gears
1241 2112 2113 2114 325 327 1168
2372 2367

Squeeze Film Bearings
2240 1237 1638

Squeeze Film Dampers
2570 71 213 2634 75 2049
1523 2569
2633

Stability
2370 2261 2 1553 1684 725 2027 2478 1579
2480 2371 742 1694 1395
1652

Stability Analysis
use Stability

Stability Methods
2479

Stabilization
1768

Staggered Solution Schemes
2254

STAGS (Computer Program)
2254

Stalling
948

Standards
use Standards and Codes

Standards and Codes
2691 1163 24 155 216 17 718 719
794 1165 376 737
824
1164
1574
2324

Statistical Analysis
1850 1871 542 913 144 2276 2497 1408 639
1972 2033 1628
2643 2498

Statistical Energy Analysis
200 2677 2499

Statistical Energy Methods
1100 144

Statistical Linearization
2497 2498

Stators
2290

Steady State Excitation
use Periodic Excitation

Steady-State Response
use Periodic Response

Steam Generators
use Boilers

Steam Turbines
1641 1742

Steel
1150 1721 972 2373 1194 1185 236 237 238 1189
1750 2441 1192 1704 1195 1186 597 1188
2641 2352 2064 1525 2176 1187 2178
2642 2094 2375 1717
2354 2097
2374 2637
2424

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2299 2299-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Steepest Descent Method

1119

Steering Effects

33

1846

Steering Gear

2651

276

Steering Wheels

use Steering Gear

Step Response

1692

2034

Stick-Slip Response

1986

Stiffened Panels

2140

98

Stiffened Plates

350

992

343

780

993

990

Stiffened Shells

1940

2164 1015 1276 2167

Stiffened Structures

1903 2384

978

Stiffener Effects

2515

2167

2527

Stiffness

2600

1584 235

2295

Stiffness Coefficients

560

1641

1582

313

884

725

586

308

319

590

1651

1642

603

2204

885

656

518

929

820

2291

2582

1133

2585

956

1758

1129

1910

2571

1683

1386

1828

1239

1809

2110

2513

1956

2376

2523

2583

Stiffness Methods

2031

1136 1127 1928

Stochastic Processes

1550 191

844 845

227 458 2259

2260 711

1634

957 728

2310 971

868

2580 1461

2018

2228

Stodola Method

1663

Storage

646

Storage Tanks

782

783

784

1673

Stress Waves

2445

Stress Analysis

2223 2224

2689

Stringers

1015

Strings

960

608 2379

Strips

1765

1257

Strouhal Number

1764

Structural Components

use Structural Members

Structural Elements

use Structural Members

Structural Members

1870

1081

1692

533

834

625

1296

667

1298

1039

1691

1163

1004

2425

2176

1157

2048

1964

2426

1297

2178

1737

2177

Structural Modification Effects

2651 2552

2367

2369

Abstract

Numbers: 1-217 218-483 484-719 720-888 889-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2891

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

- T -									
Tanks (Containers)									
1950	1951	1673	1274	1275	1277	248	1279		
			1674			1278	1949		
						1948			
						2348			
Taxiing Effects									
					947				
Taylor Series									
	2422					1778			
Temperature Effects (Excitation)									
use Thermal Excitation									
Test Data									
use Experimental Data									
Test Equipment and Instrumentation									
2010		1733	437	205	1106	1537	548	1209	
				2235		2107	1358		
				2465		2287	1538		
Test Facilities									
690	691	182	233	484	2015	1786	477	438	2649
		692	693	694			2467	658	
		2653	2014				2587	838	
			2234					2238	
			2654					2468	
Text Fixtures									
use Test Facilities									
Test Instrumentation									
use Test Equipment and Instrumentation									
Test Models									
		183							
Test Specifications									
								2289	
Test Stands									
				2585					
Testing Apparatus									
use Test Equipment and Instrumentation									
Testing Equipment									
use Test Equipment and Instrumentation									

Testing Instrumentation
use Test Equipment and Instrumentation

Testing Machines
use Test Equipment and Instrumentation

Testing Techniques									
180	681	432	2013	684	45	686	687	548	439
1090	1101	682		1164	215	1536	757	688	559
1340	1271			1574	1105	2246	1087	1298	719
2240	2011			2374	1165	2466	1357	1618	889
				2464	2245		1887	2328	1199
							2237		1209
							2287		1339
									2289

Textile Looms
1184 235

Textile Spindles
use Spindles

Thermal Conductivity
1122

Thermal Effects
1188

Thermal Excitation									
1280		1902	2603		1235	1266	67	1178	1689
		1942			2405				2029

Thermal Insulation
2549

Thermoelasticity
2200 1897 1978

Thermoviscoelasticity Theory
167

Thickness Effects
use Geometric Effects

Three Dimensional Problems
2282

Thrust Bearings									
70		1642	583			2106			78
590									
2110									

Tilting Pad Bearings
1642 315

Abstract												
Numbers:	1-217	218-483	484-719	720-886	887-1187	1188-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Time-Dependent Excitation

1913 94 126 137

Time-Dependent Parameters

431 1292 907 2608
1771

Time Domain Method

1190 201 192 1733 1954 675 826 847 1228 679
1420 931 1102 2485 2486 1847 1609
1101 1752 2279
1351
1731

Timoshenko Theory

1410 91 92 983 625 767 768 1659
2600 2382 2115 1248 1899

Tire Characteristics

1205 1887
1845

Tires

63 946 1887 308 309
1476 2359

Toroidal Shells

2166

Torque

2457

Torsion Bars

62

Torsional Excitation

352 2396 2607 1169
1589

Torsional Response

1821 333 1205 857 1889
2101 1253 1705 1477 2189
1965 2537
2587

Torsional Vibration

720 521 652 93 324 225 86 527 1168 339
950 651 1082 1663 1664 625 666 1247 2298
1720 1171 1162 1903 1814 1655 876 1417 2588
1800 1532 2103 1964 1815 1816
2510 2054 2525
2384
2494

Towed Bodies

use Towed Systems

Towed Systems

1490

Towers

240 1593 534 248 249
1190 1803 1824 2538 1999

Track Roughness

1436 59

Tracked Vehicles

747

Traction Drives

2303 2304

Tractors

743 744 745 577 578
1208

Traffic Induced Vibrations

12 385

Traffic Noise

150 811 52 13 634 1206 807 808 149
810 911 912 913 1844 907 908 809
910 1352 1233 1974 1207 909
1882 2073 1877
2622

Traffic Sign Structures

900 901 1314 1516

Trailers

742 743 744 745 906
904 905 2356
1605

Trains

use Railroad Trains

Transducers

2360 671 672 673 1726 1097 1098
2012 1723
2473

Transfer Functions

1071 382 383 1124 2086 1627 948

Abstract

Numbers: 1-217 218-483 484-718 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Transfer Matrix Method										Transverse Shear Deformation Effects									
2490	1261	92	114	2676	337	98	1419	1040	1671	1662	983	1935	2386	1927	998	109			
2510	1822	994		2417	968			1680	2332	1493					1668	779			
				2048						2103					2518	1929			
Transformation Techniques										Transverse Vibration									
			2484							1923									
Transient Excitation										Trees (Plants)									
2391	723	2125		1017	2198	1009				1974									
				1087															
Transient Response										Trucks									
2080	531	362	663	204	1265	436	117	2188	959	2350	61	1232	1433	1844	1605	1606	1097	1098	
2600	2271	472	1123	354		1146	1007	2258	2299		741	2552	2553	1854	1845				
	2611	2292	1833	474		1236	1267	2298	2409					2074	2325				
			2023	1024			1527	2599						2324					
			2033	1134			2167												
				1724															
				1954															
				2414															
Translational Inertia Effects										Trusses									
				1896			1009								976				
Translational Response										Tube Arrays									
840	1921			1825		667	2588					2413		2415		2617			
						1477													
Transmissibility										Tubes									
use Transmissivity										130	131	132	133	134	96	377	378	129	
										1020		2412	373	374	346	1797	638	1019	
										2170			403	1234	1496		1288	1289	
										2610					1796		1798	1799	
																		2169	
Transmission Lines										Tuned Dampers									
2120	961	962	2213	534	1245	1656				300	2561				2217	658			
	1161									830									
Transmission Matrix Methods										Tuned Frequencies									
						1577				720									
Transmission Systems										950									
										Tuning									
												2575	2566	1227					
Transportation Effects										Tunnels									
571				635	2076	567				2540				804					
2241						2077													
Transportation Noise										Turbine Blades									
							149			2100	312	2363			66		1478	579	
																	759		
																	2029		
Transportation Systems										Turbine Components									
use Transportation or Transportation Vehicles										1721	1992	504		1806					
Transportation Vehicles												604							
						2077													

Abstract												
Numbers:	1-217	218-483	484-719	720-886	887-1187	1188-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2891
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Turbine Engines											
1810	222			865							
				1745							
Turbines											
1810	2581	1742				1888					
	2052										
Turbocompressors											
				2596							
Turbofan Engines											
	1291					2297					
	1451										
Turbofans											
1580		1413									
Turbogenerators											
1740	2513			2506	2507						
	2573										
Turbomachinery											
220	511	72	653	1394	485	596	707	508	39		
1740	1641	512	1893	2634	2505	1806	1117	2508	489		
2280	2051	702				1996	1367		1579		
		732				2566			2539		
		2532									
Turbomachinery Blades											
2361	952	313		485							
		2103									
Turbomachinery Noise											
				1174							
Turbulence											
	131	933	614		2416	2047					
	391		774								
	2051		1944								
Turbulent Friction											
		1763									
Two-Degree of Freedom Systems											
		963		1556	1387						

- U -

Ultrasonic Tests
use Testing Techniques

Unbalanced Mass Response
1180 1411 722 493 1804 5 76 2517 1408 509
2050 732 2518 1409
2660 1739

Underdamping
2208

Underground Explosions
2191 1517 1979

Underground Structures
2540 1421 1022 793 254 255 26 797 368 619
1501 1252 1503 794 795 796 798 2419
2043 1594 1785 1498
2418

Underride Guards
use Guard Rails

Underwater Explosions
2080 471 552 2255 1049
2432 2079

Underwater Pipelines
1953 1954 896

Underwater Sound
151 1312 673 1504 1735 396 2687 1569
671 1702 2045 1969
1311 2625

Underwater Structures
620 1254 2065 56 2119
1210 1504
1490

Unified Balancing Approach
2661

Universal Joints
1802 2588

Urban Noise
1972 1233 144 1206 1879
1204 1876
2046

Urban Transportation
1851

USA (Computer Program)
2254

Abstract											
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2661											
Volume 13											
Issue:	1	2	3	4	5	6	7	8	9	10	11 12

- V -

Valves
81 82 763 1485 1026 737 1488 369
781 602 1486 1487
1051 1896 1497
2591 2116

Van Der Pol Oscillators
1328 1329

Vanes
1
2201

Vans
2326

Variable Amplitude Excitation
1984

Variable Cross Section
1800 1261 92 1933 2294 1506 337 968
1910 1262 2143 777 1178
1922 2173 2417 1268
1932 2423 1588
2122
2152
2332

Variable Material Properties
2480 2161 1852 1173 2295 876 777 1809
2521 2029

Variance Analysis
1344 1345

Variational Methods
1302 454 2025
1484
2584

Velocity
636

Velocity Measurement
1092

Ventilation
1958

Vibrating Foundations
535 967

Vibrating Structures
960 1271 1924 145 1056 977
1920 2201 2204 1565 1776 2207
2020 2454 1755
1925
2025

Vibration Absorbers
use Vibration Absorption (Equipment)

Vibration Absorption (Equipment)
300 1881 572 214 1335 658

Vibration Absorption (Materials)
302

Vibration Analysis
1930 1011 952 1243 1354 615 2436 1157 1598 1209
2231 1122 2463 2164 865 2596 2017 2568 1789
2351 1592 1415 2647 2019
2322 2395 2499
2595 2549
2649

Vibration Analyzers
1532 434 526 1728

Vibration Control
1780 521 212 3 284 55 146 497 1258 999
2310 1061 332 553 1644 295 1116 517 1728 1229
1141 1452 1183 1874 495 1336 1607 1738 1329
1161 2513 2624 915 1386 1987 2288
2651 1145 1396 2588
1855 1686
1786
2126

Vibration Dampers
651 652 2214

Vibration Damping
70 161 302 2624 75 146 307 1338 1099
480 231 972 1335 496 977 1538
811 626 1337
2216 2217
2307

Vibration Detectors
2461 173

Abstract												
Numbers:	1-217	218-483	484-719	720-886	887-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Abstract												
Numbers:	1-217	218-483	484-719	720-866	867-1167	1168-1402	1403-1574	1575-1799	1800-2046	2047-2289	2290-2504	2505-2691
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Viscoelastic Damping
630 1064 1396 2219
1150
1990

Viscoelastic Materials

1396

Viscoelastic Media

2180 412 414 427 1319
662 2029

Viscoelastic Properties

2610 2151 2212 663 104 1266 357 58 2449
944 2126 2597 338
1984 1528

Viscoelasticity Theory

2226

Viscoplastic Media

166

Viscosity

1945

Viscosity Effects

2613

Viscous Damping

300 1911 2192 423 655 2276 1077 2518 419
2512 1715 2496 1737 2598 609
1945 2209
2095

Visual Performance

53

Vortex-Induced Excitation

1327

Vortex-Induced Vibration

972 2434 85 1176 127 2388 2389

Vortex Noise

1500

Vortex Shedding

1500 131 132 1953 894 1908 2389
1790 141 1792
881
1791

Vulnerability

2246

- W -

Walls

1962 1323 384 1255 246
1963 806
1956

Warheads

2198

Warships

704

Waste Treatment

629

Water Hammer

717

Water Waves

280 271 1532 863 1254 925 547 278 739
1840 1841 2072 2314 2335 897 728
2211 2202 2334 838
1908

Waterworks

804

Wave Absorption

2446

Wave Analyzers

2645

Wave Diffraction

1701 1383 1304 1045 1046 1697 388 819
2181 2443 2444 1256 1827 1308 1699
2473 1967 1508

Wave Equation

1552

Wave Number

use Frequency

Abstract

Numbers: 1-217 218-483 484-719 720-888 889-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Wave Propagation
 400 171 412 413 414 255 1766 167 638 389
 970 2421 1302 713 1044 1055 2026 1037 1068 1969
 1350 2451 1552 733 1305 2626 1767
 1700 2442 1043 1695 2447
 2180 2452 1053 1955 2597
 2430 1983 1965 2687
 2450 2225
 2445

Wave Reflection
 1303 2446 848
 1563

Wave Refraction
 2446

Wave Scattering
 1300 1301 1562

Wave Transmission
 2162 1303 848

Waveguide Analysis
 1055 1767 1988

Waveguides
 1701 1272

Weapons Effects
 862 2087

Weapons Systems
 2094 2246

Wear
 320 172 133 2074
 1482

Wedges
 1926

Welded Joints
 184 2155 188
 2374 2375 258

Welding
 986

Wheel Shimmy
 946 947

Wheels
 2441 1992 64 65 1097 1098 2099
 2664

Wheelsets
 945 1436
 1355

Whipping Phenomena
 2163

Whirling
 1411 2592 1893 485 2516 2557 2578 489
 2363 2295 2587 519
 589
 2169

Wind-Induced Excitation
 730 291 292 293 284 805 36 1158 729
 1200 881 1152 1153 874 2425 416 1388 949
 1640 1191 1822 1593 1824 1226 2538 1389
 1441 1993 1944 1656 1429
 1871 2063 1964 1866 1589
 2536 1999

Wind Mills
 1803

Wind Tunnel Test Data
 1458

Wind Tunnel Testing
 1824 1585 1458

Wind Tunnel Tests
 1090 881 143 754 1175 1176 1217 729
 1620 1253 1054
 1584

Wind Tunnels
 2654

Wind Turbines
 312 227 1578
 872 1888
 1412

Windmills
 1640 1583 949

Wing Stores
 1220 1621 1622 1623 554 2345 1137 938 1459
 1460 1457 1458 1869
 2357

Abstract												
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691												
Volume 13												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Wire
1490

Work and Energy Balance
2514

Wood

943

Abstract											
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691											
Volume 13											
Issue:	1	2	3	4	5	6	7	8	9	10	11 12

TECHNICAL NOTES

A. Leissa and Y. Narita

Vibrations of Free Circular Plates Having Elastic Constraints and Added Mass Distributed along Edge Segments

J. Appl. Mechanics, Trans. ASME, 48 (1), pp 196-198 (Mar 1981) 3 figs, 6 refs

M.A.M. Torkamani

Method of Direct Solution to Inverse Problems

ASCE J. Engrg. Mechanics Div., 107 (2), pp 424-429 (Apr 1981) 2 figs, 6 refs

P.R. Brazier-Smith, D. Butler, and J.R. Halstead
The Determination of Propagation Path Lengths of Dispersive Flexural Waves through Structures

J. Sound Vib., 75 (3), pp 453-457 (Apr 8, 1981) 4 figs, 4 refs

S.M. Correa, D.L. Sengupta, and W.J. Anderson
Inflight Aircraft Vibration Modes and Their Effect on Aircraft Radar Cross Section

J. Aircraft, 18 (4), pp 318-319 (Apr 22, 1981) 4 figs, 6 refs

J.R. Kuttler and V.G. Sigillito

On Curve Veering

J. Sound Vib., 75 (4), pp 585-588 (Apr 22, 1981) 2 figs, 2 tables, 4 refs

C.T. Leung, N.W.M. Ko, and K.H. Ma

Heat Transfer from a Vibrating Cylinder

J. Sound Vib., 75 (4), pp 581-582 (Apr 22, 1981) 1 fig, 4 refs

S.V. Kulkarni and K.B. Subrahmanyam

Reissner Method Calculations of Natural Frequencies of Torsional Vibrations of Tapered Cantilever Beams

J. Sound Vib., 75 (4), pp 589-592 (Apr 22, 1981) 2 tables

T. Irie, G. Yamada, and M. Tsujino

Natural Frequencies of Concavely Shaped Polygonal Plates with Simply Supported Edges

J. Acoust. Soc. Amer., 69 (5), pp 1507-1509 (May 1981) 2 figs, 1 table, 10 refs

R.E. Mickens

A Uniformly Valid Asymptotic Solution for $d^2y/dt^2 + y = a + ey^2$

J. Sound Vib., 76 (1), pp 150-152 (May 8, 1981) 8 refs

J.S. Bandat

Spectral Bandwidth, Correlation Duration, and Uncertainty Relation

J. Sound Vib., 76 (1), pp 146-149 (May 8, 1981) 2 refs

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
ACTA MECHANICA Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Acta Mech.	JOURNAL OF ENGINEERING FOR POWER	J. Engrg. Power, Trans. ASME
ACUSTICA S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1 W. Germany	Acustica	JOURNAL OF ENGINEERING RESOURCES TECHNOLOGY	J. Engrg. Resources Tech., Trans. ASME
AERONAUTICAL JOURNAL Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. J.	JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech., Trans. ASME
AERONAUTICAL QUARTERLY Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. Quart.	JOURNAL OF MECHANICAL DESIGN	J. Mech. Des., Trans. ASME
AIAA JOURNAL American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	AIAA J.	JOURNAL OF PRESSURE VESSEL TECHNOLOGY	J. Pressure Vessel Tech., Trans. ASME
AMERICAN SOCIETY OF CIVIL ENGINEERS, PROCEEDINGS ASCE United Engineering Center 345 East 47th St. New York, NY 10017		APPLIED ACOUSTICS Applied Science Publishers, Ltd. Ripple Road, Barking Essex, UK	Appl. Acoust.
JOURNAL OF ENGINEERING MECHANICS DIVISION	ASCE J. Engrg. Me- chanics Div.	ARCHIVES OF MECHANICS (ARCHIWUM MECHANIKI STOSOWANEJ) Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Arch. Mechanics
JOURNAL OF STRUCTURAL DIVISION	ASCE J. Struc. Div.	ASTRONAUTICS AND AERONAUTICS AIAA EDP 1290 Avenue of the Americas New York, NY 10019	Astronaut. & Aeronaut.
AMERICAN SOCIETY OF LUBRICATING ENGINEERS, TRANSACTIONS Academic Press 111 Fifth Ave. New York, NY 10019	ASLE, Trans.	AUTOMOBILTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Abteilung Technik 7000 Stuttgart 1 Pfizerstrasse 5-7 W. Germany	Autom- obiltech. Z.
AMERICAN SOCIETY OF MECHANICAL ENGINEERS, TRANSACTIONS ASME United Engineering Center 345 East 47th St. New York, NY 10017		AUTOMOTIVE ENGINEER (SAE) Society of Automotive Engineers, Inc. 400 Commonwealth Drive Warrendale, PA 15096	Auto. Engr. (SAE)
JOURNAL OF APPLIED MECHANICS	J. Appl. Mechanics, Trans. ASME	AUTOMOTIVE ENGINEER (UK) P.O. Box 24, Northgate Ave. Bury St., Edmunds Suffolk IP21 GBW, UK	Auto. Engr. (UK)
JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME	BALL BEARING JOURNAL (English Edition) SKF (U.K.) Ltd. Luton, Bedfordshire LU3 1JF, UK	Ball Bearing J.
JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engrg. Indus., Trans. ASME	BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.
		BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES Am Polona-Ruch 7 Krokowakie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS Japan Society of Mechanical Engineers Sanshin Hokusai Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan	Bull. JSME	HEATING/PIPING/AIR CONDITIONING Circulation Dept. 614 Superior Ave. West Cleveland, OH 44113	Heating/ Piping/ Air Cond.
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826 Berkeley, CA 94705	Bull. Seismol. Soc. Amer.	HYDRAULICS AND PNEUMATICS Penton/IPC, Inc. 614 Superior Ave. West Cleveland, OH 44113	Hydraulics & Pneumatics
CIVIL ENGINEERING (NEW YORK) ASCE United Engineering Center 345 E. 47th St. New York, NY 10017	Civ. Engrg. (N.Y.)	HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
CLOSED LOOP MTS Systems Corp. P.O. Box 24012 Minneapolis, MN 55474	Closed Loop	IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers Struc.	INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
DESIGN ENGINEERING Berkshire Common Pittsfield, MA 02101	Des. Engrg.	INGENIEUR-ARCHIV Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Ing. Arch.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Des. News	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS IEEE United Engineering Center 345 East 47th St. New York, NY 10017	IEEE
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P.O. Box 7406 Milwaukee, WI 53213	Diesel Gas Turbine Prog.	INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminster, London SW1, UK	IMechE Proc.
ENGINEERING MATERIALS AND DESIGN IPC Industrial Press Ltd. 33-40 Bowling Green Lane London EC1R, UK	Engrg. Matl. Des.	INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222	ISA Trans.
ENGINEERING STRUCTURES IPC Science and Technology Press Ltd. Westbury House P.O. Box 63, Bury Street Guildford, Surrey GU2 5BH, UK	Engrg. Struc.	INSTRUMENTATION TECHNOLOGY Instrument Society of America 67 Alexander Drive P.O. Box 12277 Research Triangle Park, NC 27709	InTech.
EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P.O. Box 277 Westport, CT 06880	Exptl. Mechanics	INTERNATIONAL JOURNAL OF CONTROL Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK	Intl. J. Control
FEINWERK U. MESSTECHNIK Carl Hanser GmbH & Co. D-800 Munchen 86 Postfach 860420 Fed. Rep. Germany	Feinwerk u. Messtechnik	INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016	Intl. J. Earthquake Engrg. Struc. Dynam.
FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139 Graf-Recke Str. 84 4 Düsseldorf 1 W. Germany	Forsch. In- genieurwesen	INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engrg. Sci.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
INTERNATIONAL JOURNAL OF FATIGUE IFI Science and Technology Press Ltd. P.O. Box 63, Westbury House, Bury Street Guildford, Surrey, England GU2 5BH	Intl. J. Fatigue	JOURNAL OF ENGINEERING MATHEMATICS Academic Press 198 Ash Street Reading, MA 01867	J. Engrg. Math.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.	JOURNAL OF ENVIRONMENTAL SCIENCES Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.	JOURNAL OF FLUID MECHANICS Cambridge University Press 32 East 57th St. New York, NY 10022	J. Fluid Mechanics
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlin. Mechanics	JOURNAL OF THE FRANKLIN INSTITUTE Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engrg.	JOURNAL OF HYDRONAUTICS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Hydro- nautics
INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS John Wiley and Sons, Ltd. Baffins Lane Chichester, Sussex, UK	Intl. J. Numer. Anal. Methods Geomech.	JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA Science House, 157 Gloucester Sydney, Australia 2000	J. Inst. Engr., Austral.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Solids Struc.	JOURNAL DE MECANIQUE Gauthier-Villars C.D.R. - Centrale des Revues B.P. No. 119, 93104 Montreuil Cedex-France	J. de mecanique
INTERNATIONAL JOURNAL OF VEHICLE DESIGN The International Assoc. of Vehicle Design The Open University, Milton Hall Milton Keynes MK7 6AA, UK	Intl. J. Vehicle Des.	JOURNAL OF MECHANICAL ENGINEERING SCIENCE Institution of Mechanical Engineers 1 Birdcage Walk, Westminster London SW1 H9, UK	J. Mech. Engrg. Sci.
ISRAEL JOURNAL OF TECHNOLOGY Weizmann Science Press of Israel Box 801 Jerusalem, Israel	Israel J. Tech.	JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mechanics Phys. Solids
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.	JOURNAL OF PETROLEUM TECHNOLOGY Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206	J. Pet. Tech.
JOURNAL OF AIRCRAFT American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Aircraft	JOURNAL OF PHYSICS: E SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	J. Phys. E: Sci. Instrum.
JOURNAL OF THE AMERICAN HELICOPTER SOCIETY American Helicopter Society, Inc. 30 East 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.	JOURNAL OF SHIP RESEARCH Society of Naval Architects and Marine Engineers 20th and Northampton Sts. Easton, PA 18042	J. Ship Res.
		JOURNAL OF SOUND AND VIBRATION Academic Press 111 Fifth Ave. New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Spacecraft Rockets	NOISE AND VIBRATION CONTROL Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Vib. Control
JOURNAL OF TESTING AND EVALUATION (ASTM) American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	J. Test Eval. (ASTM)	NOISE CONTROL ENGINEERING P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603	Noise Control Engrg.
KONSTRUKTION Spring Verlag 3133 Connecticut Ave., N.W. Suite 712 Washington, D.C. 20008	Konstruktion	NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS, TRANSACTIONS Bolbec Hall Newcastle upon Tyne 1, UK	NE Coast Instn. Engrs. Shipbldrs., Trans.
LUBRICATION ENGINEERING American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068	Lubric. Engrg.	NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P.O. Box 3489 Amsterdam, The Netherlands	Nucl. Engrg. Des.
MACHINE DESIGN Penton Publishing Co. Penton Bldg. Cleveland, OH 44113	Mach. Des.	OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne Tulsa, OK 74101	Oil Gas J.
MASCHINENBAUTECHNIK VEB Verlag Technik Oranienburger Str. 13/14 102 Berlin, E. Germany	Maschinen- bautechnik	PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engrg.
MECCANICA Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Meccanica	PLANT ENGINEERING 1301 S. Grove Avenue Barrington, IL 60010	Plant Engrg.
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 East 45th St. New York, NY 10017	Mech. Engrg.	POWER P.O. Box 521 Hightstown, NJ 08520	Power
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mechanics Res. Comm.	POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	Power Transm. Des.
MECHANISM AND MACHINE THEORY Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory	QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mechanics Appl. Math.
MEMOIRS OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engrg. Kyoto Univ.	REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MECANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumaine 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mecanique Appl.
MTZ MOTORTECHNISCHE ZEITSCHRIFT Franksche Verlagsbuchhandlung Pflzerstrasse 5-7 7000 Stuttgart 1 W. Germany	MTZ Motor- tech. Z.	REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.
NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bldg. 1012 - 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.	SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.
		SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.	VDI FORSCHUNGSHEFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Düsseldorf 1, Germany	VDI Forsch.
STROJNICKY ČASOPIS Red. Strojnického Časopisu ČSAV A SAV USTAV MECHANIKY STROJOV SAV Bratislava-Patronka, Dubrovská cesta, ČSSR Czechoslovakia	Strojnický Časopis	VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviatt Rd. Bay Village, OH 44140	S/V, Sound Vib.	VIBROTECHNIKA Kauno Polytechnikos Institutas 2 Donelaičio g-ve 17 233000 Kaunas Lithuanian SSR	Vibro- technika
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen-ATM	WAVE MOTION North Holland Publishing Co. P.O. Box 211 1000 AE Amsterdam The Netherlands	Wave Motion
TEST 61 Monmouth Road Oakhurst, NJ 07755	Test	WEAR Elsevier Sequoia S.A. P.O. Box 851 1001 Lausanne 1, Switzerland	Wear
TRIBOLOGY INTERNATIONAL IPC Science and Technology Press Ltd. Westbury House P.O. Box 63, Bury Street Guildford, Surrey GU2 5BH, UK	Tribology Intl.	ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepziger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.	ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	Z. Flugwiss
VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Düsseldorf 1, Germany	VDI Z.		

SECONDARY PUBLICATIONS SCANNED

GOVERNMENT REPORTS ANNOUNCEMENTS & INDEX NTIS U.S. Dept. of Commerce Springfield, VA 22161	GRA	DISSERTATION ABSTRACTS INTERNATIONAL University Microfilms Ann Arbor, MI 48106	DA
SCIENTIFIC AND TECHNICAL AEROSPACE REPORTS Superintendent of Documents U.S. Government Printing Office Washington, D.C. 20402	STAR		

ANNUAL PROCEEDINGS SCANNED

INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.	THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Center Naval Research Lab., Code 5804 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
TURBOMACHINERY SYMPOSIUM Gas Turbine Labs Texas A&M University College Station, Texas	Turbomach. Symp.		

CALENDAR

FEBRUARY 1982

- 22-26 SAE Congress and Exposition [SAE] Detroit, MI (SAE Hqs.)

MARCH 1982

- 29-Apr 1 Design Engineering Conference and Show [ASME] Chicago, IL (ASME Hqs.)
- 30-Apr 1 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Oak Brook, IL (Ronald L. Eshleman, Director, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)

APRIL 1982

- 14-16 Fatigue Conference & Exposition [SAE] Dearborn, MI (SAE Hqs.)
- 18-22 Gas Turbine Conference and Products Show [ASME] London, England (ASME Hqs.)
- 20-22 Mechanical Failures Prevention Group 35th Symposium [National Bureau of Standards] Gaithersburg, MD (Dr. James G. Early, National Bureau of Standards, Bldg. 223/Room A-113, Washington, DC 20234 - (301) 921-2976)
- 20-23 Institute of Environmental Sciences' 28th Annual Technical Meeting [IES] Atlanta, GA (IES, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)
- 22-23 13th Annual Pittsburgh Conference on Modeling and Simulation [School of Engineering, Univ. of Pittsburgh] Pittsburgh, PA (William G. Vogt or Merlin H. Mickle, Modeling and Simulation Conf., 348 Benedum Engrg. Hall, Univ. of Pittsburgh, Pittsburgh, PA 15261)
- 26-30 Acoustical Society of America, Spring Meeting [ASA] Chicago, IL (ASA Hqs.)

MAY 1982

- 12-14 Pan American Congress on Productivity [SAE] Mexico City (SAE Hqs.)
- 24-26 Commuter Aircraft and Airline Operations Meeting [SAE] Savannah, GA (SAE Hqs.)

JUNE 1982

- 7-11 Passenger Car Meeting [SAE] Dearborn, MI (SAE Hqs.)

JULY 1982

- 13-15 'Environmental Engineering Today' Symposium and Exhibition [SEE] London, England (SEE, Owles Hall, Buringford, Herefordshire, UK)
- 19-21 12th Intersociety Conference on Environmental Systems [SAE] San Diego, CA (SAE Hqs.)

AUGUST 1982

- 16-19 West Coast International Meeting [SAE] San Francisco, CA (SAE Hqs.)

SEPTEMBER 1982

- 13-16 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI (SAE Hqs.)

OCTOBER 1982

- 4-6 Convergence '82 [SAE] Dearborn, MI (SAE Hqs.)
- 4-7 Symposium on Advances and Trends in Structural and Solid Mechanics [George Washington Univ. and NASA Langley Res. Ctr.] Washington, DC (Prof. Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Res. Ctr., Hampton, VA 23665 - (804) 827-2897)
- 12-15 Stapp Car Crash Conference [SAE] Ann Arbor, MI (SAE Hqs.)
- 25-28 Aerospace Congress & Exposition [SAE] Anaheim, CA (SAE Hqs.)

NOVEMBER 1982

- 8-12 Acoustical Society of America, Fall Meeting [ASA] Orlando, Florida (ASA Hqs.)
- 8-12 Truck Meeting & Exposition [SAE] Indianapolis, IN (SAE Hqs.)
- 14-19 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Phoenix, AZ (ASME Hqs.)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, NJ 07645	IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, NY 10017
AGMA:	American Gear Manufacturers Association 1330 Mass Ave., N.W. Washington, D.C.	IES:	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056
AHS:	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036	IFTOMM:	International Federation for Theory of Machines and Mechanisms U.S. Council for TMM c/o Univ. Mass., Dept. ME Amherst, MA 01002
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, NY 10019	INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
AIChE:	American Institute of Chemical Engineers 345 E. 47th St. New York, NY 10017	ISA:	Instrument Society of America 400 Starwix St. Pittsburgh, PA 15222
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, IL 60605	ONR:	Office of Naval Research Code 40084, Dept. Navy Arlington, VA 22217
ARPA:	Advanced Research Projects Agency	SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096
ASA:	Acoustical Society of America 335 E. 45th St. New York, NY 10017	SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, UK
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, NY 10017	SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, CT 06880
ASME:	American Society of Mechanical Engineers 345 E. 45th St. New York, NY 10017	SNAME:	Society of Naval Architects and Marine Engineers 74 Trinity Pl. New York, NY 10006
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, IL 60202	SPE:	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, WI 53203	SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 5804 Washington, D.C. 20375
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	URSI-USNC:	International Union of Radio Sciences - U.S. National Committee c/o MIT Lincoln Lab. Lexington, MA 02173
CCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada		
ICF:	International Congress on Fracture Tohoku Univ. Sendai, Japan		

**PUBLICATIONS AVAILABLE FROM
THE SHOCK AND VIBRATION INFORMATION CENTER
CODE 5804, Naval Research Laboratory, Washington, D.C. 20375**

PRICES
Effective - 1 September 1981

SHOCK AND VIBRATION DIGEST

SVD-14 (Jan. - Dec. 1982)

U.S.	FOREIGN
\$140.00	\$175.00

SHOCK AND VIBRATION BULLETINS

SVB-47	\$ 15.00	\$ 18.00
SVB-48	30.00	37.50
SVB-49	30.00	37.50
SVB-50	60.00	75.00
SVB-51	100.00	125.00
SVB-52	140.00	175.00

SHOCK AND VIBRATION MONOGRAPHS

SVM-2, Theory and Practice of Cushion Design	\$ 10.00	\$ 12.50
SVM-4, Dynamics of Rotating Shafts	10.00	12.50
SVM-5, Principles and Techniques of Shock Data Analysis	5.00	6.25
SVM-6, Optimum Shock and Vibration Isolation	5.00	6.25
SVM-7, Influence of Damping in Vibration Isolation	15.00	18.75
SVM-8, Selection and Performance of Vibration Tests	10.00	12.50
SVM-9, Equivalence Techniques for Vibration Testing	10.00	12.50
SVM-10, Shock and Vibration Computer Programs	10.00	12.50
SVM-11, Calibration of Shock and Vibration Measuring Transducers	25.00	31.25
SVM-12, Balancing of Rigid and Flexible Rotors	50.00	62.50

SPECIAL PUBLICATIONS

An International Survey of Shock and Vibration Technology	\$ 30.00	\$ 37.50
The Environmental Qualification Specification as a Technical Management Tool	12.00	15.00

To order any publication, simply check the line corresponding to that publication that appears below, and mail the postage free card. You will be invoiced at the time of shipment.

Please send the following publication(s) to me:

Name _____

Address _____

Mail invoice to: (if other than above)

<input type="checkbox"/> SVD-14	<input type="checkbox"/> SVM-5
<input type="checkbox"/> SVB-47	<input type="checkbox"/> SVM-6
<input type="checkbox"/> SVB-48	<input type="checkbox"/> SVM-7
<input type="checkbox"/> SVB-49	<input type="checkbox"/> SVM-8
<input type="checkbox"/> SVB-50	<input type="checkbox"/> SVM-9
<input type="checkbox"/> SVB-51	<input type="checkbox"/> SVM-10
<input type="checkbox"/> SVB-52	<input type="checkbox"/> SVM-11
<input type="checkbox"/> SVM-2	<input type="checkbox"/> SVM-12
<input type="checkbox"/> SVM-4	
<input type="checkbox"/> International Survey	
<input type="checkbox"/> Qual. Spec. Report	

DEPARTMENT OF THE NAVY

**NAVAL RESEARCH LABORATORY, CODE 5804
SHOCK AND VIBRATION INFORMATION CENTER
Washington, D.C. 20375**

**OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, \$300**

**POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316**



**The Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington D.C. 20375**

PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].

Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined

- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December Issues)
- volume, number or issue, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Pletzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (1962).
4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).
5. Lendehi, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).
7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

Articles for the DIGEST will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the DIGEST. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 1500 to 2500 words in length. For additional information on topics and editorial policies, please contact:

Milda Z. Tainulionis
Research Editor
Vibration Institute

101 West 55th Street, Suite 206
Clarendon Hills, Illinois 60514

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY, CODE 5804
SHOCK AND VIBRATION INFORMATION CENTER
Washington, D.C. 20375

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, \$300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316



2-
RECEIVED DIRECTORATE OF THE
NAVY RESEARCH LABORATORY
WASHINGTON, D.C. 20375

THE SHOCK AND VIBRATION DIGEST

Volume 13, No. 12

December 1981

EDITORIAL

- 1 SVIC Notes
- 2 Editors Rattle Space

- 25 Annual Article Index
- 27 Book Reviews
- 30 Book Reviews: 1981

ARTICLES AND REVIEWS

- 3 Feature Article - FINITE-ELEMENT
MODELING OF LAYERED, ANISO-
TROPIC COMPOSITE PLATES AND
SHELLS: A REVIEW OF RECENT
RESEARCH
J.N. Reddy
- 13 Literature Review
- 15 VORTEX SHEDDING FROM CYLIN-
DERS AND THE RESULTING UN-
STEADY FORCES AND FLOW PHE-
NOMENA, PART II
S.T. Fleischmann and D.W. Sallet

CURRENT NEWS

- 33 Short Courses
- 35 News Briefs
- 36 Information Resources

ABSTRACTS FROM THE CURRENT LITERATURE

- 39 Abstract Categories
- 40 Abstract Contents
- 41 Abstracts: 81-2505 to 81-2691
- 87 Annual Author Index
- 113 Annual Subject Index
- 169 Technical Notes
- 170 Periodicals Scanned

CALENDAR